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COMPREHENSIVE GROUNDWATER

MONITORING EVALUATION (CME)

LOCKWOOD CORPORATION NED044101442

NEBRASKA DEPARTMENT OF ENVIRONMENTAL CONTROL

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Lockwood Corporation NED044101442
SW¼, SE¼, Sec. 1, T. 21N, R. 55W, 6th P.M.
Scotts Bluff County, Nebraska

Technical Assessment

A. Introduction

I. General Background

Lockwood Corporation is a Nebraska corporation engaged in the manufacture of dump truck body hoists, pumps, hydraulic cylinders, truck bodies, center pivot irrigation systems, potato harvesters, and potato planters. Manufacturing processes include machining, forging, welding, galvanizing, fabrication, phosphatizing, painting, and assembly. Hazardous wastes generated include spent pickle liquor (D002, formerly K062), waste acid sludge (D002), waste caustic sludge (D002), waste petroleum naphtha (D001), waste MEK, xylene, and toluene solvents (F003/F005), and waste paint sludges (F003/F005/D001).

Lockwood currently ships its spent pickle liquor to Gibraltar Chemical Resources, Inc. of Winona, Texas (TXD000742304) for disposal. Formerly it disposed of this waste in either of two existing surface impoundments. Galvanizing operations commenced during 12/72; an estimated 1.40 to 2.24 million gallons of spent pickle liquor were pumped into the impoundments. Use of these lagoons ceased during 6/84 as a result of an NDEC Administrative Order.

II. Chronological Summary of RCRA Enforcement.

Lockwood Corporation initially notified U. S. EPA that they were a TSD for D001 and D002 (8/13/80). U. S. EPA removed Lockwood from the Hazardous Waste Data Management System on 6/3/81. NDEC conducted its initial Hazardous Waste Compliance inspection on 8/18/82; subsequent chemical analysis of Lockwood's waste streams resulted in their revised notification on 5/23/83, once again indicating that Lockwood was a TSD for D001 and D002. Another NDEC CEI occurred on 3/7/84, information from which prompted (6/20/84) NDEC to instigate an Administrative Order for Lockwood to cease use of the impoundments and study the environmental impact of their past use. On 7/24/84 an interpretive memo from the U. S. EPA Office of Solid Waste determined that waste pickle liquor from galvanizing processes should be considered K062. NDEC conducted another CEI on 7/16/85, reviewing the status of Lockwood's various waste streams. On 9/6/85 Lockwood submitted a closure plan for their RCRA regulated surface impoundments. On 10/8 -10/85 NDEC witnessed installation of ten assessment monitoring wells. On 1/30/86

Lockwood submitted a Subsequent Notification indicating that it was a Generator and TSD for F003 and F005 as well as K062 liquid and sludge and caustic sludge (D002). On 2/21/86 NDEC sent Lockwood Corporation an L.O.W. requiring groundwater monitoring data. On 5/28/86 the Federal Register included a ruling that resulted in changing the status of Lockwood's spent pickle liquor from K062 to D002. NDEC conducted another CEI on the Lockwood facility on 6/2/86. On 7/9/86 NDEC approved Lockwood's closure and post-closure plans for the surface impoundments.

III. Regulatory Status.

Lockwood Corporation is currently undergoing closure in accordance with 40 CFR 265 subpart G. Their closure and post-closure plans have been approved. Lockwood has installed ten RCRA assessment monitoring wells in accordance with 40 CFR 265.90(d). Lockwood is currently on a monthly groundwater monitoring schedule by NDEC requirement (L.O.W. 2/21/86).

IV. Sampling History.

Early chemical results (2/12/81. 4/13/84. and 5/6/84) indicated that Lockwood wastes exceeded E. P. Toxicity thresholds for lead. cadmium. arsenic. selenium. and chromium and that pH of fluids in the impoundments had at some times declined beneath the 2.0 threshold at 40 CFR 261.22(a)1. Later groundwater samples (8/27/84. 11/9/84. 11/7/85. 2/25/86. 4/10/86) have indicated chromium. lead. silver. selenium. and arsenic concentrations in excess of EPA Interim Primary Drinking Water Standards. Chromium and lead concentrations are currently within the Standards.

B. History of the Regulated Surface Impoundment and Its Monitoring

At the Lockwood Corporation site are two (2) inactive surface impoundments. sharing a common dike. The dikes are earthen. with slopes of 3:1 and heights between 2 and 4 feet. The southernmost basin. with a calculated capacity of about 269.259 gallons. is the older of the two. The northernmost basin. with a calculated capacity of about 403.889 gallons. is provided with a bentonite liner (1 lb/sq. ft., roughly 1/4 inch thickness. of powderized Volclay bentonite (with a density of about 66 lb/ft^3) disced into native soil to a depth of about 6 inches with an ASTM standard compaction of about 95% of D698 density. or a permeability of about 0.002 ft/day. 7 x 10^{-7} cm/s. about the upper limit of permeability of shale or unweathered marine clay).

The southernmost basin (Cell #1) was constructed in November 1972. At this time it probably had a calculated capacity similar to that of the present day Cell #2. which did not then exist. Galvanizing began at the Lockwood facility during December 1972. This unlined impoundment received batch discharges of waste pickle liquor (a 5 to 15% sulfuric acid solution) neutralized with anhydrous ammonia. averaging 5.000 to 8.000 gallons twice monthly from December. 1972. until February. 1978.

At some undetermined time during the winter of 1977-1978, the Lockwood Corporation was contacted by the North Platte Natural Resource District, which required an easement for the construction of an unlined flood control and irrigation runoff drainage ditch which would of necessity intersect the then-active Cell #1. The NRD proposed to shorten Cell #1 and construct a new and better, clay-lined impoundment of the same capacity immediately adjacent to, and utilizing a common berm with, Cell #1 all at the NRD's expense. The earthen dikes of the new Cell #2 were to be composed of material salvaged from dikes of the old southern portion of Cell #1, including bottom sludges, as well as newly excavated material. Engineering efforts for this project were supplied by the local Soil Conservation Service office. Design specifications are in accordance with the then-current edition of the SCS Engineering Field Manual. A similar design and construction was utilized in the fish pond at the Scottsbluff V. A. Home.

NDEC approved a permit for construction of Cell #2 on 1/13/78. It was completed and put into service during February, 1978, and received wastes twice monthly until June, 1984.

On 8/13/80 U. S. EPA received a First Notification of Hazardous Waste Activity from Lockwood that indicated that it was a TSD (Treat/Store/Dispose) facility for ignitable (D001) and corrosive (D002) wastes. An EPA identification number was subsequently assigned.

On 2/12/81 chemical samples of dry sludge, wet sludge and "pond" water were analyzed. A copy of this analysis is included in the appendix to this report. The water sample was not analyzed for pH, yet heavy metal concentrations are quite high, indicating that pH was probably very low. Lead, Cadmium, Arsenic and Selenium concentrations were well in excess of the E. P. Toxicity thresholds of 40 CFR 261.24, Table 1.

On 3/3/81 Lockwood discussed with U. S. EPA the necessity of applying for a part "A" RCRA permit form. U. S. EPA indicated that the amount and method of waste treatment was not sufficient for the "storage" category.

On 6/3/81 U. S. EPA notified Lockwood that it was now considered a non-handler of hazardous waste and that it had been removed from the Hazardous Waste Data Management System.

On 8/18/82 NDEC conducted a hazardous waste compliance inspection at Lockwood, the report of which indicated doubt as to the non-handler status of the facility. This inspection incorrectly identified Cell #2 as a plastic-lined pit.

On 4/1/83 NDEC notified Lockwood that they were required to sample their paint sludges (thought to have been disposed of on-site or sent to the Gering Landfill) and lagoon sludge.

A revised Notification of Hazardous Waste Activity was submitted by Lockwood on 5/23/83, indicating that it was a TSD for D001 and D002.

An NDEC hazardous waste compliance inspection was again undertaken on 3/7/84. This inspection indicated that 36,000 gal/mo of D002 were neutralized and sent to the surface impoundment at this time. It identified the neutralizing chemical as anhydrous ammonia, and contained the first photographs of the impoundments.

On 3/15/84 NDEC requested chemical analysis of several specific sample points in the facility waste stream. NDEC ruling on facility status to be contingent upon these results. Results were required within 30 days.

On 4/3/84 an NDEC hydrogeologist completed preliminary investigation of the site, noting the existence of Gering Industrial Well No. 2, a municipal well with a normal pumping rate of 1200 gpm, within 2000 feet of the site.

On 4/13/84 NDEC received chemical analysis of samples from several critical points in the waste stream, including E. P. Toxicity tests of neutralization tank and evaporation pit sludges and evaporation pit fluid pH, and heavy metal analysis. These analyses indicated that neither sludge was E. P. Toxic, but the impoundment fluid had a pH of 0.5 and high Cadmium (56 ppm) and Chromium (42 ppm) levels (see Appendix).

On 4/18/84 NDEC conducted on-site investigation and sampling. Samples from the municipal well, the lagoon sludge, the neutralizer tank sludge, the paint booth sludge, and two nearby private wells, were taken. A circular shaped erosion pit was noted immediately beneath the lagoon inlet pipe. Sampling occurred only six days after a 5,000 gallon neutralized waste pickle liquor discharge into the lagoon, yet no free liquid was noted.

Assuming that the base of Cell #2 is 90 feet square.

$$5000 \text{ gallons} \times \frac{0.133680555 \text{ ft3}}{\text{gallon}} = 668.40 \text{ ft}^3$$

$$(90 \text{ ft})^2 = 8,100 \text{ ft}^2$$

$$668.40 \text{ ft}^3 \div 8,100 \text{ ft}^2 = .08 \text{ ft.}$$

$$.08 \text{ ft} \times \frac{12 \text{ inches}}{\text{ft}} = .99 \text{ or } 1 \text{ inch}$$

Therefore if the lagoon was lined so that it was perfectly impervious to water, a 5000 gallon discharge would yield one inch of fluid. The SCS evaporation constant for Scottsbluff in April is 0.1 inches/day. Over six days, 0.6 inches would be expected to evaporate, leaving 0.4 inches (or 2000 gallons).

$$2000 \text{ gal}/6 \text{ days}/8100 \text{ ft}^2 = 0.04 \text{ field permeability coefficient}$$

$$0.04 \text{ gal/day/ft}^2 = 7.16 \times 10^{-8} \text{ ft/sec.} = 0.01 \text{ ft/day}$$

USCS considers 1×10^{-2} ft/day "very low permeability".

This is about the lowest permeability anticipated from silt or loess. A permeability test conducted (presumeably on a test pad) at the Scottsbluff V.A. Home fishpond, the liner of which was designed and installed in an identical fashion to that at Cell #2, yielded 0.002 ft/day. Assuming applicability of this value to the uneroded liner of Cell #2, erosion increased the effective practical permeability by five times.

Chemical results from the samples taken at this time (see Appendix) indicate that leachable metals from all of the sludges were less than the maximum allowable concentrations (40 CFR 261.24, Table 1). The leachable metals from the municipal and private well water samples were also below the critical limits of the recommended drinking water quality standard. The pH of the neutralizer tank sludge was found to be 1.7, thus identifying it as a hazardous waste by virtue of its corrosivity (see Appendix). This latter judgement was communicated to Lockwood by NDEC in a letter of 7/17/84 after receipt of an inquiry from Lockwood about the status of the acid tank, preflux tank and neutralization tank sludges. The same letter advised that preflux tank and acid tank sludge be disposed of as hazardous waste, though the 5/8/84 and 5/17/84 E. P. Toxicity results indicated that neither was toxic.

On 5/6/84 Lockwood reported additional chemical results on the neutralized acid standing in Cell #2: pH 2.9, Cd 65 ppm, Cr 42.1 ppm, Pb 4.2 ppm (see Appendix).

On 5/21/84 NDEC received from Lockwood a request for guidance with respect to monitoring well location and design.

On 6/13/84 Lockwood informed NDEC: 1) that it had engaged the services of an engineering consulting firm; 2) that a new spent acid neutralization pit was then under construction; 3) that it had applied for licensing with the State of Oklahoma for deep well injection disposal of its spent acid waste; and 4) that it proposed, and sought NDEC approval for, construction of yet another evaporation lagoon, larger and with both an impermeable membrane and a bentonite liner.

On 6/20/84 NDEC sent an Administrative Order to Lockwood, ordering that it "immediately cease discharge of wastes into the evaporation pond currently being used", and within thirty days provide both a plan for disposal of pond sludges and "a hydrogeologic study to determine the extent of contamination of ground water, if any, which may have resulted from the seepage from the evaporation pond." It also ordered sampling of all affected water supply wells.

On 7/20/84 Lockwood informed NDEC that: 1) the PVC effluent line to Cell #2 had been flushed, disconnected and capped on 6/26/84; 2) hydrogeologic field work had occurred from 6/6 - 9/84, prior to the administrative order, and additional work, including borings and samplings, was completed by 7/12/84; 3) Lockwood requested extension of the deadline for the hydrogeologic study and closure plan; 4) the State of Oklahoma had approved of deep well injection of Lockwood's spent sulfuric acid: and 5) six truckloads, totalling 28,300 gallons, had been sent to Tulsa between 6/28/84 and 7/18/84.

An interpretive memo from the Office of Solid Waste (7/24/84) determined that waste pickle liquor from galvanizing processes should be considered K062.

On 8/3/84 NDEC contacted Hoskins, Western, and Sonderegger (HWS), Lockwood's engineering consultant, who indicated that Cd and Cr "had been found" in the groundwater but that unavoidable delays necessitated an extension of the 30-day deadline for completion of the hydrogeologic study specified in the Administrative Order. NDEC approved a 30-day extension in a letter to Lockwood dated 8/3/84.

On 8/27/84 NDEC received a preliminary hydrogeologic report from HWS (see Appendix). This report summarized chemical analysis of water from eleven shallow auger borings taken within a 150 feet radius of the impoundments. It was concluded that chromium concentration declines radially away from the site: zinc and cadmium concentrations show no trend. Chromium concentrations greatly exceeded drinking water standards (40 CFR 265 Appendix III). Lead concentrations were not analyzed. This document concludes that lagoon leakage did occur, resulting from erosion of the clay liner beneath the point of entry of the discharge pipe.

An NDEC hydrogeologic review (9/16/84) of the above document was critical of several details of reporting of chemical analysis and choice of parameters tested.

On 9/12/84 pH and E. P. Toxicity samples were taken from several drums of galvanizing waste (unspecified) at the site by HWS.

On 9/27/84 NDEC contacted HWS requesting an estimated completion date of the final hydrogeologic study. Response: 11/1/84. Also requested were lead concentration data and heavy metal analysis for soils beneath Cell #2 and in the site area, and clarification of reporting anomalies.

On 10/19/84 HWS contacted Lockwood primarily regarding design of new, lined evaporation lagoons.

On 11/9/84 NDEC received the final Hydrogeologic Investigation and Remedial Action Plan. The report advised closure of Cell #2 with removal of all sludge and liner, emplacement of a graded, low permeability cap, and installation of groundwater monitoring to satisfy 40 CFR 265.91(a). It recommended sampling for chromium, lead, sulfate and specific conductance. It also proposed a plan to acid wash the contaminated soils, to remobilize the heavy metals so that they could be recovered by remedial action pumping of the four (4) newly-proposed RCRA assessment monitoring wells. It concluded, once again, that groundwater contamination had occurred, resulting from erosion beneath the intake pipe. Chromium, lead, zinc, sulfate, and iron all occurred above background levels. Specific conductance varied from 800 to 8,200 umhos without consistent pattern of decline with increasing radii from the site. A chromium concentration of 0.14 mg/l was detected as far as 325 feet from the site of the erosion through the liner of Cell #2. A lead concentration of 0.10 mg/l occurred at the same location. Sulfate concentrations as high as 1,295 mg/l are recorded. There are several analytical inconsistencies in the chemical result tables of the report. The pH of samples was found to decline with greater radial distance from the site.

On 11/21/84 the above document was reviewed by NDEC (see Appendix). This review advised water level readings at the time of each sampling, field filtering of turbid samples, continued determination of dissolved hexavalent chromium concentration, and placement of monitoring wells in a north-south line through point B-11, 50 feet west of B-14, and at the location of B-16. It also questioned the validity of certain interpretations of the significance of chemical data.

On 12/15/84 NDEC received copies of chemical analyses of additional auger boreholes and lagoon sludge samples. All samples were received at Western Lab on 7/18/84. Most samples showed very high levels of zinc (as high as 1,300 mg/l), but lower than threshold values for E. P. Toxicity in all other parameters.

On 12/6/84 NDEC was informed that E. P. Toxicity tests were currently underway on samples of about 200 55-gallon drums of acid waste sludge, caustic waste sludge and preflux sludge (these are the samples that were reported as taken on 9/12/84).

On 12/10/84 NDEC completed review of the Hydrogeological Investigation document.

This review indicated that the proposed monitoring system contained inadequate capability to monitor background chemistry. It advised a third well on the western side of the impoundments to provide additional downgradient monitoring. It noted that analysis methods were not detailed; suggested shallow soil chemical sampling; indicated that intentional acid-leaching of the precipitated metals to recovery wells was environmentally unsafe; was critical of analysis reporting procedures, sampling location and chemical parameter choices, and the lack of piezometric and flow rate data. It also suggested field filtering of turbid samples.

On 1/7/85 NDEC received a supplement to the Hyd. Invest. from HWS. This supplement contained E. P. Toxicity analysis of sludge (and clay liner) and/or sediment recovered in the auger holes, chemical data from which was first received on 12/15/84. All results tabulated indicated no E. P. Toxic hazard; however, review indicates that the reported vertical intervals of analysis are not continuous. For example, auger boring B-3 was sampled from 3.5 to 4.0 feet and again from 10.5 to 11.0 feet. The conclusions reported in this supplement are as follows: 1) the sludge, liner, and soils are non-hazardous; 2) the mobile toxic metals (those recorded in ground water samples) are the result of a single excursion due to the liner erosion; 3) "natural alkalinity is neutralizing the acid front and immobilizing the toxic metals"; and 4) "with cessation of evaporation pond use the source of pollution was ended." This document continues with recommendations that the site be clay capped and that excavation and removal of sludge and sediment are not necessary because they are not E. P. Toxic.

On 1/9/85 NDEC received chemical analysis of samples from the storage drum lots at Lockwood. These are the samples that were the subject of correspondence on 9/12/84 and 12/6/84). They indicate that samples are neither corrosive nor E. P. Toxic.

On 1/14/85 NDEC completed review of the supplemental hydrogeologic report. This review questioned the single excursion of conclusion 2, noted that zinc concentrations increased downward in the sediments beneath the erosion pit of Cell #2, and advised soil sampling in 6" to 1' increments.

On 1/21/85 HWS provided chemical analysis of Lockwood's paint used in normal production. This waste paint is hazardous characteristically and by virtue of containing listed components; however, NDEC was assured that this waste was neither disposed in the acid-dip tank nor in the sewer.

On 2/22/85 Lockwood representatives were invited to attend a meeting at NDEC concerning K062 issues. The meeting took place on 2/28/85. The options presented were delisting and/or closure (40 CFR 265 and 270) of the impoundments and continued off-site disposal, or licensing (40 CFR 264 and 270), or a fertilizer exemption, or an exemption as a flocculant aid for a wastewater treatment system, or exemption by discharge into an NPDES permitted municipal wastewater treatment system (POTW). A response from each galvanizer as to which option would be selected was requested by 4/1/85. This request was followed by a written reminder on 3/14/85.

NDEC called Lockwood 4/1/85, having received no response. Lockwood indicated that they had reached no decision. NDEC called again on 4/10/85. Lockwood indicated that a response would be sent very soon. On 4/11/85 HWS, on behalf of Lockwood, responded that Lockwood would "identify, collect and manifest to a licensed hazardous waste disposal facility" its K062.

On 6/7/85 HWS called NDEC to inquire about the strict RCRA status of sludge produced in pretreatment of K062 prior to disposal to an NPDES permitted municipal wastewater treatment facility (POTW). NDEC responded that this sludge would be considered K062. On 6/2/85 HWS followed up with a written inquiry and NDEC responded in writing on 6/19/85.

On 6/21/85 NDEC made formal response to Lockwood's Hyd. Invest. (11/9/84) and the Supplemental Report (1/7/85): recommending ten (10) specific monitoring well locations, soliciting technical comments with respect to these locations by 7/15/85; requiring submittal of a groundwater monitoring plan and a closure and post-closure plan by 7/26/85; requiring completion of well installations by 9/15/85 and completion of initial sampling by 11/15/85. NDEC conclusions were that: 1) a potential existed for continued contamination and migration in the groundwater; 2) the proposed monitoring network was minimal and not appropriate to a site where groundwater contamination had already been detected; 3) a silty sand "layer" was encountered in boring logs of B-3, B-4, and B-10, and may represent a potential route of contaminant migration; 4) there were problems with HWS' data collection and interpretation techniques; 5) HWS mentioned (Hyd. Invest., p. 10, para. 2, sentence 1) a previously used waste acid pit -- the original Cell #1, which was reduced in size during 2/78 -- yet failed to note that B-3 and B-6 were located within the original limits of Cell #1; 6) field filtering of turbid samples was necessary; 7) piezometric and flow rate data are necessary; and 8) concentrations of sulfates were found to exceed the 250 ppm recommended drinking water quality standard, therefore COD, BOD, sulfide and TOC should be analyzed.

On 7/16/85 NDEC conducted a hazardous waste compliance inspection. Discrepancies noted involved posting of required signs and storage of barrels of contaminants beyond the acceptable time.

On 7/22/85 HWS, through Lockwood, responded to NDEC's letter of 6/21/85. This response constituted the solicited technical comments due by 7/15/85, and also served as a groundwater monitoring plan.

The HWS response restates that "an excursion has occurred at the Lockwood spent acid evaporation ponds." It indicates that the Hyd. Invest. had already addressed the issues of fluid density, fluid pH, intrinsic properties of the aquifer, hydrostatic head, and duration of connection of the pond to the aquifer; however the work appeared limited with respect to determination of fluid density or duration of connection of the pond to the aquifer, and intrinsic properties of the aquifer were not thoroughly explored (unconsolidated cores were not taken for porosity determination and grain size histograms were not constructed). The document proposes installation of ten (10) assessment monitoring wells, two of them of 8-inch diameter and the rest of 4-inch diameter, the former to be used as the principal, and the latter the piezometer, wells in a proposed 8- to 24-hour pump test, the common steps of which are detailed. The author(s) intended to apply this test to determine storage coefficient, transmissivity, and net hydraulic conductivity. The final recommendation of the HWS submittal is the application of a clay cap over the impoundments.

The document also responds to specific NDEC (6/21/85) comments. With respect to NDEC Item #3 (as summarized above), HWS acknowledges that the "layer" in question does represent a relative high permeability conduit, but that the ultimate fate, after lateral (near surface) dispersal, is "aquifer Unit 2" (the lower portion of the braided stream deposit overlying the Brule), groundwater from which was sampled in the auger borings in close proximity to the site. This response does not consider that a K062 batch discharge may have saturated this relative high permeability "layer", and thus occasioned near surface lateral migration prior to sinkage of the denser-than-water plume into the braided stream deposit. Such an event may complicate effective monitoring by necessitating difficult vadose zone soil monitoring in the upper Unit 1 of a particular portion of the site.

With respect to NDEC comment #8 (as summarized above), HWS indicates that the background sulfate concentration is naturally high and that "no evidence was detected of reducing conditions." The former statement is quite true. Background concentrations as high as 255 ppm were noted in Gering municipal well T3 (65-2). However auger boring groundwater sample sulfate concentrations between 915 and 1295 ppm (such as B-1, B-3, B-4, and B-10), were found which are in the closest downgradient borings to the impoundments.

On 7/22/85 USEPA notified Lockwood that Section 213(a) of the Hazardous and Solid Waste Amendments of 1984 (HSWA, Public Law 98-616) amends Section 3005(e) of the Solid Waste Disposal Act (SWDA) such that Lockwood's interim status land disposal facility would lose interim status on 11/8/85 unless Lockwood submitted a RCRA Part B permit application and certified that it was in compliance with 40 CFR 265 subpart F and H.

On 7/24/85 HWS advised Lockwood that its submittal to NDEC serving as a groundwater monitoring plan was deficient with respect to "frequency of long-term groundwater sampling and specific analyses to be performed." The letter goes on to advise Lockwood that, "these parameters require the recommended 24-hour aquifer test . . .". HWS went on to advise well installation and initial sampling and analysis, the latter to determine whether the sampled fluids are characteristically hazardous. Once determined, if samples are not determined characteristically hazardous, then application should be made to NDEC for a discharge permit for fluids pumped out during the pump test (50 gpm for 24 hours). The intended destination of this fluid was the Gering Drain.

During a telephone conversation of 8/20/85 between Lockwood and NDEC, it was agreed that the ten (10) monitoring well locations proposed by Lockwood on 7/17/86 were acceptable. NDEC followed this call with a letter on the same date, also recommending that the "dynamic testing of the aquifer" (or pump test) not be performed unless subsequent data warranted it.

On 10/3/85 NDEC provided Lockwood with detailed comments regarding its groundwater monitoring plan. NDEC specified: 1) that gravel pack sizing be determined on the basis of the standard procedures utilizing aquifer grain size analysis; 2) sampling frequency (monthly for the first four months, thereafter to be determined); 3) analytical parameters; 4) that soil samples from the auger borings be chemically analyzed; 5) that metal analysis be performed on both filtered and unfiltered samples for half of the initial sampling events; and 6) that monthly groundwater elevation data be collected.

On 10/8 - 10/85 NDEC was on-site during the drilling of eight of the ten (10) groundwater monitoring wells. NDEC noted that: 1) HWS was using a rotary rig and poly gel so that acquisition of an undisturbed soil sample was not possible. The reliability of future pH determination was doubtful in any wells drilled with poly gel -- a caustic drilling mud; 2) no decontamination procedures were utilized; 3) cement was poured directly onto the gravel pack without a bentonite seal between the two; 4) there was no rationale stated for the development pumping rate or duration; 5) the engineering design of gravel pack grain size parameters and screen slot size was sound.

On 11/13/85 Lockwood certified that it was in compliance with 40 CFR 265 Subpart F.

On 11/21/85 HWS notified NDEC that groundwater samples were taken from the ten (10) assessment monitoring wells on 11/7 - 8/85.

On 1/30/86 Lockwood submitted a Subsequent Notification of Hazardous Waste Activity, adding to its previous notification that they were also a Generator and TSD for F003 and F005 solvent wastes as well as 300,000 gal/yr of K062 liquid, 50,000 lbs/yr K062 sludge, and 15,000 lbs/yr D002 caustic sludge.

On 2/14/86 NDEC called Lockwood and informed them that NDEC would proceed with public notice of the closure plan after receiving ground water analytical data.

On 2/20/86 NDEC called HWS requesting the analytical data from the 11/7/85 sampling. HWS indicated that the data would be sent to NDEC.

On 2/21/86 NDEC sent Lockwood a Letter of Warning, requiring receipt of the (11/7/85) data by 3/7/86 and requiring that sampling events be scheduled in March, April, and May, while specifying a schedule for data submittal.

A groundwater monitoring event occurred on 2/25/86. Wells MI-1 and MI-2 were not sampled.

On 3/7/86 NDEC received the analytical results of the 11/7/85 sampling event (see Appendix). The pH of samples ranged from 6.7 to 7.7, while background values range from 7.3 to 8.1. Specific Conductance ranged from 1340 to 3600 umhos/cm, while local surface water ranges from 455 to 1180. Iron concentrations ranged from < .03 to 5.2, while background concentrations are from 0.0 to 0.1. The Pb EPA Interim Primary Drinking Water Standard is 0.05 mg/l, while all HWS analyses reported "< 0.1 mg/l". Sodium concentrations ranged from 157 to 430 mg/l, while background ranges from 84 to 239 mg/l. Zinc concentrations ranged from 0.020 to 0.712 mg/l, while background concentrations ranged from 0.012 to 0.027 mg/l. Manganese concentrations ranged from < 0.1 to 3.9 mg/l, while background concentrations range from 0.00 to 0.05 mg/l. Fluoride concentrations ranged from 0.4 to 3.9 mg/l, while the EPA Interim Primary Drinking Water Standard is 1.4 to 2.4 mg/l. Sulfate concentrations ranged from 80 to 2000 mg/l, while the maximum recorded background concentration is 280 mg/l. The analytical results did show evidence of contamination.

On 4/8/86 HWS called NDEC to indicate that a groundwater sampling event would occur on 4/10/86. It was agreed that NDEC would split four (4) samples with HWS and that each party would analyze these for all of the quarterly sampling parameters. the remaining six (6) wells would be sampled by HWS alone and analyzed only for the monthly parameters. A Compliance Monitoring and Enforcement Log (CMEL) to EPA was prepared on 3/10/86 to reflect that Lockwood was meeting its compliance schedule with respect to the Letter of Warning.

On 4/10/86 HWS and NDEC split-sampled four (4) monitoring wells at the site. The NDEC samples were turned over to the NDEC Laboratory on 4/11/86.

On 5/16/86 the NDEC Laboratory completed its analysis of the split samples taken at Lockwood on 4/10/86.

On 5/28/86 the Federal Register contained a final rule pertaining to the listing of K062. The net effect of this ruling was that the waste pickle liquor produced by Lockwood was no longer to be considered K062, a listed waste, but was now to be considered D002, a characteristic waste. Lockwood was notified of the existence of this ruling on 6/4/86.

NDEC went to public notice with its intention to approve the RCRA closure plan for the Lockwood surface impoundments on 5/29/86. The public notice period ended 7/1/86.

On 6/2/86 NDEC conducted a RCRA Compliance Inspection at Lockwood, the report of which was published 6/30/86.

On 7/9/86 NDEC informed Lockwood that it modified and approved the closure and post-closure plans for the surface impoundments.

On 8/6/86 NDEC received groundwater monitoring results of a sampling event conducted on 2/25/86. These did not include results from MI-1 or MI-2, nor were pH or specific conductivity included (the data for these parameters had been copied by the author from HWS's field notebook on 4/10/86).

On 8/21/86 NDEC received HWS's analytical results from the split sampling event of 4/10/86.

Table 1 - Compilation of Analytical Results of Groundwater Monitoring of the Assessment Monitoring Wells to Date

	M-1			M-2			M-3		
	11/7/85	2/25/86	4/10/86	11/7/85	2/25/86	4/10/86	11/7/85	2/25/86	4/10/86
SC umhos/cm	2800	3800	2600	1580	1400	1500	1780	1600	1500
pH	7.0	7.2	6.9	7.5	7.3	7.3	7.4	7.5	7.3
Cd mg/l (d)	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cr mg/l (d)	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Pb mg/l (d)	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Fe mg/l (d)	4.3	3.04	3.2	<.03	<.05	<.05	.21	.54	.69
Mn mg/l (d)	2.5	2.6	2.1	<.01	<.01	<.01	.42	.32	.35
Na mg/l (d)	148	164	147	223	232	220	175	183	178
Zn mg/l (d)	.399	.379	.353	.020	.017	.033	.167	.166	.159
+As mg/l(t)	.002	.004	--	.021	.024	--	.006	.026	--
Ba mg/l (t)	.2	.50	--	<.1	.14	--	.1	.33	--
Cd mg/l (t)	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cr mg/l (t)	<.05	<.05	<.01	<.05	<.05	<.01	<.05	<.05	<.05
Fe mg/l (t)	5.2	5.70	9.16	.03	8.2	.35	1.52	2.89	4.28
Pb mg/l (t)	<.1	<.1	<.025	<.1	<.1	<.025	<.1	<.1	<.025
Hg mg/l (t)	<.0002	<.0002	--	<.0002	<.0002	--	<.0002	<.0002	--
Se mg/l (t)	<.002	<.002	--	<.002	.013	--	<.002	.007	--
Ag mg/l (t)	.11	.08	--	.02	<.01	--	<.01	<.01	--
Na mg/l (t)	157	167	148	298	240	229	233	183	178
Zn mg/l (t)	.387	.491	.38	.02	.825	.20	.173	.234	.27
Mn mg/l (t)	2.5	2.2	1.65	<.01	21	2.98	.42	.36	.34
Cl mg/l (t)	26	25	26	29	30	31	23	27	27
Sulfate mg/l	1050	915	920	275	300	406	430	326	540
TOC mg/l	5-4	5	5	5-6	5	--	4-5	5	--
Phen mg/l	<.05	<.05	.08	<.05	<.05	--	<.05	<.05	--
TOH ug/l	18.22	<20	<50	19-24	44	--	15.20	<15	--

(d) = dissolved; (t) = total

Table 1 (Cont.)

	M-4			M-5			M-6		
	11/7/85	2/25/86	4/10/86	11/7/85	2/25/86	4/10/86	11/7/85	2/25/86	4/10/86
SC umhos/cm	3600	5450	4800	1250	1000	900	1530	1200	1300
pH umhos/cm	6.7	6.9	6.8	7.4	7.5	7.4	7.5	7.5	7.5
Cd mg/l (d)	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cr mg/l (d)	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Pb mg/l (d)	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Fe mg/l (d)	2.05	3.60	3.0	.21	.05	<.05	.21	<.05	<.05
Mn mg/l (d)	3.9	5.0	4.5	<.01	.02	.02	.34	.12	.15
Na mg/l (d)	333	315	324	163	178	173	188	208	216
Zn mg/l (d)	.425	.574	.622	.013	.035	.02	.033	.031	.056
+As mg/l(t)	<.002	.003	--	.026	.018	--	.019	.023	--
Ba mg/l (t)	.2	.62	--	.1	.18	--	.1	.16	--
Cd mg/l (t)	<.005	.005	.005	.005	.005	.005	.005	.005	.005
Cr mg/l (t)	<.05	<.05	.03	<.05	<.05	<.01	<.05	<.05	<.01
Fe mg/l (t)	2.75	7.50	8.3	.27	.60	.08	.50	1.0	.70
Pb mg/l (t)	<.1	<.1	<.025	<.1	<.1	<.025	<.1	<.1	.03
Hg mg/l (t)	<.0002	<.0002	--	<.0002	<.0002	--	<.0002	<.0002	--
Se mg/l (t)	<.002	.005	--	<.002	.002	--	<.002	.006	--
Ag mg/l (t)	.02	<.01	--	.02	<.01	--	<.01	<.01	--
Na mg/l (t)	430	348	320	203	176	172	275	214	220
Zn mg/l (t)	.464	.659	.73	.712	.970	.04	.05	.067	.05
Mn mg/l (t)	3.9	4.8	4.2	.04	.10	.10	.34	.14	.13
Cl mg/l (t)	140	115	92	37	33	32	27	27	27
Sulfate mg/l	2000	1830	1630	80	30	150	275	268	332
TOC mg/l	6	6	5	4	4	3	4-5	5	--
phen mg/l	<.05	<.05	.06	.06	.06	.13	.13	.13	--
TOH ug/l	33-41	26	<100	15-20	<20	<100	20-38	<20	--

(d) = dissolved; (t) = total

Table 1 (Cont.)

	M-7			M-8		
	11/7/85	2/25/86	4/10/86	11/7/85	2/25/86	4/10/86
SC umhos/cm	1460	1150	1300	1410	1100	1100
pH umhos/cm	7.5	7.4	7.4	7.7	7.5	7.5
Cd mg/l (d)	<.005	<.005	<.005	<.005	<.005	<.005
Cr mg/l (d)	<.05	<.05	<.05	<.05	<.05	<.05
Pb mg/l (d)	<.1	<.1	<.1	<.1	<.1	<.1
Fe mg/l (d)	.13	.05	.05	<.03	<.05	<.05
Mn mg/l (d)	<.01	<.01	<.01	<.01	<.01	<.01
Na mg/l (d)	198	163	218	195	174	209
Zn mg/l (d)	.044	.028	.026	.037	.026	.020
+As mg/l (t)	.023	.18	--	.021	.20	
Ba mg/l (t)	.1	.18	--	.1	.18	--
Cd mg/l (t)	<.005	<.005	<.005	<.005	<.005	<.005
Cr mg/l (t)	<.05	<.05	<.01	<.05	<.05	<.01
Fe mg/l (t)	.22	.52	.14	.73	.39	.16
Pb mg/l (t)	<.1	<.1	<.025	<.1	<.1	<.025
Hg mg/l (t)	<.0002	<.0002	--	<.0002	<.0002	--
Se mg/l (t)	<.002	.004	--	<.002	.004	--
Ag mg/l (t)	<.01	.03	--	.05	.01	--
Na mg/l (t)	258	166	217	230	176	207
Zn mg/l (t)	.02	.400	.04	.049	.217	.05
Mn mg/l (t)	<.01	.06	.01	.02	.02	.02
Cl mg/l (t)	29	26	30	19	24	27
Sulfate mg/l	120	106	306	120	164	320
TOC mg/l	4-5	5	--	4	4	4
Phen mg/l	<.05	<.05	--	<.05	<.05	<.05
TOH ug/l	21-32	<20	--	20-24	<20	<50

(d) = dissolved; (t) = total

C. Regional Geology

I. Precambrian through Tertiary

The site is located near the axis of the Denver-Julesburg Basin (Figure 1 and 4). A hypothetical stratigraphic well drilled at the Lockwood Corporation site would encounter a Proterozoic granitic and metamorphic complex (1.55 - 1.70 b.y.a.; USGS "Y") at about 7500 ft (-3720 feet M.S.L.). This rock is part of the Central Plains Province belt of continental accretion around an Archean nucleus in north-central Wyoming. The top of the Precambrian represents a major unconformity, overlain by Lower Pennsylvanian deposits (Figure 2 and 3). This unconformity is the result of an Early Pennsylvanian orogenic episode, topographically expressed as the Ancestral Rocky Mountains. Pennsylvanian deposition amounted to about 900 feet of rock, cyclothemic repetitions of full or or partial sequences of shale, coal, limestone, siltstone and sandstone. These strata are referred to as the Hartville or Minnelusa "formation" and include Atokan (about 60 feet), Des Moines (about 370 feet), Missouri (about 250 feet), and Virgil (about 220 feet) Series. Significant unconformities have been noted at the bottom and near the top of the Missouri Series, no doubt due to spasmodic orogenic activity. The Permian/Pennsylvanian contact (about -2800 feet M.S.L.) is unconformable. Permian deposits account for about 1500 feet of cyclothemic deposits with progressively increasing occurrences of red shale, salt, anhydrite, and gypsum. These rocks represent the Big Blue (about 600 feet) and Cimarron (about 900 feet) Series and primarily comprise the old Phosphoria Group, including the Opeche, Minnekahta and (possibly) Spearfish formations. The Jurassic/Permian contact (about -1300 M.S.L.) is obviously unconformable. Jurassic strata include the Sundance (about 410 feet) and Morrison (about 110 feet) formations. The former is sandstone-dominated at the base and becomes progressively more shale-rich. The Morrison includes both shales and limestones. The Jurassic Strata therefore apparently represent a very general transgressive sequence. The Cretaceous/Jurassic contact (about -780 feet M.S.L.) is unconformable. The Lower Cretaceous is represented by the Dakota Group, composed of the Cloverly (Fall River and Lakota Sandstones) Formation, the Skull Creek Shale and the "J" member of the Omadi Sandstone. The Dakota is about 450 feet thick at this location. The Upper Cretaceous is about 3825 feet thick (in stratigraphic order): the Graneros Shale (about 400 feet), composed of the gray calcareous Mowry shale below and the argillaceous Belle Fourche (pronounced "foosh") shale above; the Greenhorn Limestone (about 50 feet), containing interbedded gray limestone and gray shale; the Carlile Shale (about 250 feet), interbedded gray sandstone and blue shale; the Niobrara Chalk (about 275 feet), composed of about 50 feet of Fort Hayes limestone overlain by about 225 feet of gray, shaly Smoky Hill chalk; and finally about 2850 feet of Pierre (pronounced "pier") shale. The latter is usually included within the Montana group, while the former units from Graneros Shale through the Niobrara are considered within the Colorado Group. The top of the Cretaceous (about + 3495 feet M.S.L.) is the third major unconformity in the section (the first being Pennsylvanian/Precambrian, representing 1205 m.y. of missing geologic record and the second Jurassic/Permian representing 50 m.y. of missing record. This unconformity represents a 30 m.y. gap in the geologic column and is the result of the Laramide Orogeny (80-40 m.y.a.) that produced the current Rocky Mountains. The Conservation and Survey Division of UNL has published a configuration of the "Early Tertiary (Principally Pre-Chadron) Drainages and Divides" in this area (BCT-11). It indicates that the Pierre surface unconformity had a dendritic drainage, a tributary of which, immediately underlying the site, drained NNE in a generally East-flowing pattern. This surface was intensely weathered and an oxidized zone (the "Interior Paleosol") was developed during pre-Chadron and Chadron times. This zone may have been subsequently eroded off of the Pierre surface at the locality of the site. Subsequent to this, all of the Cenozoic deposition is continental, derived from western sources in the Hartville, Laramie, and Front Range uplifts and from the Black Hills to the north west. Locally, the Upper Cretaceous Pierre Shale is unconformably overlain by the Tertiary (Early Oligocene) Chadron formation (about 150 feet), alluvial valley fill sediments dated at 37 to 33 m.y.a. The lower Chadron is composed of fine-to coarse-grained sandstones and locally occurring conglomerates. These are overlain by gray and greenish-gray bentonite claystones and mudstones (Swinehart et al, 1985, p. 213). The basal sands are probably about 100 feet thick: the site lies within a major contemporary NW-SE trending tributary of a large eastwardly flowing fluvial system that infilled the paleotopographic low areas on the Pierre surface. The basal sand deposition was followed by pyroclastic air-fall debris. This eolian deposition continued for about 7 m.y.: a large volume of rhyolitic volcanic ash derived from eruptions in the western U. S. (Figure 5) resulted in the accumulation of a low-relief depositional plain with a few narrow drainages. Alteration of this pyroclastic debris resulted in the development of bentonitic beds. About 33 m.y.a. deposition of the Chadron formation ceased and Brule formation deposition began with the Orella member (about 210 feet thick). The contact is surprisingly continuous. The Orella deposition continued for about 2 m.y., with about 53 $\pm$ 14% glass shards in very fine grained sand (0.04 mm mean grain size) according to Swinehart et al, 1985 (p. 219). The Orella member contains a regionally correlative ash bed, the "M ash", somewhere from about 30 to 50 feet above the base. This member also probably contained an intraformational unconformity about 300 feet above the base, subsequently eroded off at this location. Brule Formation deposition continued at least until 29 m.y.b.p., and Arikaree, Ogallala group, and Pliocene (about 4 to 2.5 m.y.a.) Broadwater Formation braided stream deposition followed, with several interformational unconformities resulting from Miocene uplifts that resurrected the virtually buried Rock Mountains, but none of this record is represented at the immediate locality of the site. Quaternary braided stream deposits (25 feet thick) overlie the Brule (Orella member) in the forth major unconformity immediately beneath the site, representing 30 m.y. of missing geologic record. The petrology and provenance of these braided stream deposits, and those of the Broadwater, are described by Stanley and Wayne, 1972.

II. Pleistocene through Recent

A. Braided Stream Deposits

Had the Pliocene Broadwater Formation braided stream deposits survived erosion here, they would have been immediately overlain by Lower Pleistocene anorthosite-bearing braided stream deposits. Significant lithologic differences would have been discernible. According to Stanley (1971), this uppermost deposit contains 50 ± 9% Sherman-type granite, less than 1% graphic granite, 12 ± 8% orthoclase, 7 ± 3% anorthosite, 12 ± 5% quartz and quartzite, 3% gneiss, 5 ± 2% schist, 3% chert, 2 ± 1% sandstone, and less than 1% rhyolite clasts. The average intermediate diameter of the ten largest clasts may be as much as 20 cm. The Broadwater gravels elsewhere are described as containing 64 ± 10% Sherman-type granite, 1% graphic granite, 20 ± 7% orthoclase, 0% anorthosite, 2% chert, a trace of sandstone, and 2% rhyolite clasts. Sherman granite detritus is derived from the front ranges of the Rocky Mountains in Wyoming and Colorado. The average intermediate diameter of the ten largest clasts is about 9 cm.

Stanley and Wayne (1972) explained the differences as follows:

> "The change from Pliocene to Pleistocene fluvial sedimentation in Nebraska is denoted by gravel with relative enrichment of mechanically weak rock species and a two-fold increase in largest clast size. These changes in fluvial sediments suggest modification in degradational energy affecting detritus apparently related to deterioration of climate in the early Pleistocene. Cooler Pleistocene climates with increased moisture resulted in greater discharge and carrying capacity for streams headed in the Rocky Mountains and flowing across Nebraska" (Stanley and Wayne, 1972, p. 3625).

Internal stratigraphic geometry within the Pleistocene terrace is almost certainly lensatic. Miall braided stream depositional types are probably "Scott" and "Platte" (Miall, 1978, p. 599).

B. Soils

The soil overlying the Early Pleistocene terrace appears to be relatively deep and is the result of *in situ* weathering of colluvium derived from the calcareous siltstone of the Brule, comprising the hill slope west of the site. U. S. Geological Survey WSP 943 (1946) indicates that the soils of the "first-bottom or flood plain" belong to the Laurel, Minatare and Orman series, while "terrace, or second-bottom soils" belong to the Tripp and Cheyenne series. These series are described as follows:

> The Tripp series is characterized by a loose surface soil within a heavier subsoil layer and is developed on the low alluvial terraces of the North Platte River and its larger tributaries. The Cheyenne series has a porous substratum and no heavy subsoil layer, but its mode of occurrence is similar to that of the Tripp. The Laurel series, occupying the flood plain, is a thin soil developed on a coarse alluvium. Soils of the Minatare series are plastic, fine-grained, dark-colored, poorly drained, and alkaline. They overlie a substratum of gravel. The Orman series is dark and impervious and contains much organic matter (USGS WSP 943, p. 12).

The County soil survey (1968) general soil map indicates the Mitchell-Otero-Buffington Association for the site. The accompanying text notes that this soil occurs on nearly level topography, nevertheless it erodes readily. Mitchell soil predominates; it is deep and has a light to moderately dark limey surface layer with a light, medium-textured, lime-rich subsoil.

The attached 1:20000 scale detailed soil map sheet indicates that the site is borderline between Mitchell silt loam 0 to 1 percent slopes, and Mitchell silt loam, wet variant, 0 to 1 percent slopes. In a general Mitchell profile the following sequence is seen:

> ". . . the surface layer is light brownish-gray silt loam about 11 inches thick. It has weak granular structure in the upper part and in the lower part weak prismatic structure. This layer has a moderate amount of lime and is mildly alkaline to moderately alkaline.
>
> Beneath the surface layer is about 8 inches of grayish-brown silt loam. This layer has subangular blocky structure, is rich in lime, and is mildly alkaline. It is slightly hard when dry and friable when moist.
>
> The substratum is light brownish-gray silt loam. It is rich in lime, is mildly alkaline, and extends to a depth of more than 5 feet. In the upper part, this layer has subangular blocky structure and is friable when moist. The lower part is massive, or structureless. It is soft when dry and very friable when moist." (Soil Survey, p. 36).

Specific description of the Mitchell silt loam, 0 to 1 percent slopes, adds little information pertinent to this site. Discussion of the "wet variant", however, indicates that a perched water table is common in this soil within the Gering Valley at about 36 inches depth. Also ". . . the surface layer is gray or grayish brown, which is darker than is typical for Mitchell soils. This layer is about 20 inches thick, but in a few areas it is light colored and only about 8 inches thick. In most areas the layer beneath the surface layer has faint brownish mottles above the water table. The profile is limey throughout."

The General Soil Map of Scottsbluff Area (1982) by the Soil Conservation Service and the UNL Conservation and Survey Division, refers to the site soil as part of the Mitchell - Otero Association: "deep, nearly level to moderately steep, well drained, silty and loamy soils formed in weathered siltstone and loamy sediments on terraces and foot slopes: Ustic Torriorhents, coarse-silty; Ustic Torrithents, coarse-loamy." The attached soil characteristics chart lists this association as having a percentage composition of 70 (Mitchell) and 25 (Otero); its topographic position is on terraces and foot slopes (Mitchell) or strictly on foot slopes (Otero): slope percent is 0-15; parent material is weathered siltstone (Mitchell) or loamy sediments (Otero); soil is deep; it is well-drained; surface texture is silt loam (Mitchell) and sandy loam (Otero): and subsoil texture is the same.

Hydrologic Characteristics of Nebraska Soils (USGS WSP 2222) contains a generalized hydrologic soil group map which indicates that the site soils' 60-inch profile has a permeability range of 2.0 to 5.0 inches per hour, a maximum slope percentage of 10 to 20, and a depth to water of more than 6 feet. The same publication contains a hydrologic soil group map of the Scottsbluff Quadrangle. This map includes the following comment relative to the soil covering the site: "These soils are common in transitional areas between the sandhills and silty uplands and are represented by the Kenesaw-Hersh and Oglala-Jayem associations". An attached table yields the following additional pertinent date: average permeabilty of a 60-inch soil profile is 3.29 inches per hour: average permeability of the lease permeable horizon is 2.93 inches per hour: average available water capacity is 0.18 inches per inch: and average maximum soil slope is 12 percent. This publication also contains a tabulated comparison of several soil associations, among them the Mitchell-Otero, Kenesaw-Hersh and Oglala-Jayem:

Association	Ave. K of 60" profile (inches/hr)	Ave. K of least perm. horizon	Ave. Avail. water capacity (inches/inch)	Ave. Max. Soil Slope (%)
M-O	4.45	4.45	0.17	15
K-H	2.03	2.03	0.19	11
O-J	2.52	2.52	0.18	11

Current implications of "Mitchell-Otero Association" are of a much more permeable, and presumably coarser-grained, soil than is thought to exist at the site. The site soils are remarkably homogenous, implying a colluvial host sediment rather than fluvial. This in turn implies a Brule source, which lends credence to the interpretation of homogeneity.

The average water capacities cited are rather low: the earlier reference to particularly saturated conditions in the vicinity of the site has no necessary relation to the water capacity parameter. It should also be noted that the Kenesaw-Hersh and Oglala-Jayem associations are apparently more typical on steeper slopes than exist at the site (measured at 0.5 to 1.0 percent).

C. Aquifer Characteristics

1. Physical Dimensions and Configuration
Unconsolidated Sediment

The UNL Conservation and Survey Division maintains files of registered irrigation wells, municipal and industrial water wells, and miscellaneous wells (test borings, water quality sampling wells, etc.). Within about three miles of the site there are thirteen irrigation wells, twelve municipal and industrial water wells, and twelve exploratory soil borings (for gravel deposits). About six miles away is a USGS groundwater sampling well (number 22N55W11DDC). Isopach mapping of unconsolidated sediment in the site area, based upon interpretation of drillers' logs from these wells, indicates that: 1) the site is underlain by about 20-30 feet of unconsolidated silt, sand and gravel; 2) the site is part of an extensive terrace thickening to the NE and occupying all of the Gering Valley, a major tributary channel for the Early Pleistocene Platte River drainage; 3) although well spacings are relatively great, drillers' logs indicate that depositional stratigraphy is apparently highly lensatic. Even a cursory review of these logs, given the proximity of the Platte and its current depositional style, would be sufficient to conclude that these are terrace deposits relict from a much more competent, higher discharge braided stream. The highly lensatic style of deposition seen here naturally leads considerable doubt with respect to lateral hydraulic continuity of the terrace. It is possible that the site overlies high relative permeability lenses that are in direct, but highly circuitous, hydraulic contact with the Gering Drain (to the south through southeast, about 1/3 mile distant at its closest point) and with the Platte River (to the north, about 1 1/2 miles distant at its closest point).

The configuration of a terrace is classically considered to be irregularly prismatic; in this instance the terrace may most accurately be visualized as a wedge or blanket deposit thickening to the north and northeast.

Brule Formation (Orella Member)

The thickness of the Brule beneath the site is perhaps debatable. the geologic cross-sections within USGS WSP943 clearly indicate a strong structural dip to the NNE on the Brule/Chadron contact. The Brule thickens in that direction, having been truncated and overlain by the Gering Formation of the Arikaree Group at a much shallower dip. Cross-section B-B' indicates a thickness of about 200 feet of Brule at a point directly north of Scotts Bluff National Monument and at the edge of both the North Platte River and the Quaternary alluvium. This is roughly on strike with, and at the same topographic elevation as, the site under study. Tabulation of stratigraphic thicknesses of all geologic units mapped across this locality in readily accessible publications leaves slightly more than 200 feet to be accounted for as Brule Formation (see earlier discussion under "I. Precambrian through Recent"). On the other hand, the Hydrogeologic Investigation and Remedial Action Plan, Spent Acid Evaporation Pond, Lockwood Corporation, Gering, Nebraska (11/84), hereafter referred to as "Hydrogeologic Investigation", contains a geologic cross-section as Figure 2 that indicates about 35-50 feet of Brule. The most direct evidence for confirmation of Brule thickness is probably the registered municipal water well G-56972 (6-29-77), recorded as having been drilled in the NW/4 of the SE/4 of Section 1, T. 21N, R. 55W. (It is interesting to note that the well location section drawing indicates that the well is in the NE/4 of the SW/4.) The driller's log indicates a first occurrence of "soft white clay" at 45 feet, "Brule 30% firm" at 50 feet, and clay down to 270 feet. It was assumed that the clay, sand and sandstone from 270 to 305 feet were basal Brule channels (in accordance with comments on p. 67 of WSP 943), whereupon Chadron Formation was encountered. Therefore the driller, Mike Shaul of Shaul Drilling in Gering, interpreted 255 feet as Brule.

2. Reservoir Parameters

Unconsolidated Sediment

USGS WSP 943 (p. 79-82) indicates that the unconsolidated sediment has an average field coefficient of permeability of 1,398 gallons of water per day under prevailing conditions per mile of saturated strata (measured at a right angle to the flow direction), per foot of strata thickness, for each foot per mile of hydraulic gradient. It also indicates a specific yield (volume of water that the reservoir strata will yield to gravity, divided by the reservoir volume) much greater than 1.8%.

USGS WRI Report 82-4014 (9/83) contains state-wide map coverage of several aquifer parameters for the High Plains Aquifer: hydraulic conductivity, specific yield, annual pumpage, transmissivity, water recoverable per square mile, and annual water table decline. At the Lockwood Corporation site regional hydraulic conductivity is 200 to 250 ft/day, transmissivity is 5,000 to 6,250 feet^2 ft/day, specific yield is 20 to 25%, annual pumpage in 1980 was 0.0 to 1.5 inches, the volume of water recoverable from one square mile of aquifer is 3,200 to 4,000 acre-feet, and annual water level decline in 1980 was less than half a foot.

Brule Formation

USGS WSP 943 (p. 83-86) indicates that the coefficient of permeability of the Brule is from 4 to 7 (4 to 7 gallons of water at 60 F would percolate through a cross-section one mile wide and one foot thick at a hydraulic gradient of one foot per mile), however it also notes that cracks and fissures, which are very common in the Brule, would greatly increase the field coefficient of permeability depending on the size, number, and interconnection of the openings. Several measurements of the field coefficient of permeability, ranging from 243 to 889 and averaging 573, are cited. A coefficient of 573 is the equivalent of about 55 half inch pipes across the same cross-section and along the same gradient. The same document indicated an average specific yield of 29.6 (one cubic foot of Brule will yield 0.296 cubic foot of water).

D. Background Groundwater Chemistry

USGS WSP 943 contains discussion and tabular data relating to the chemical character of groundwater from the Quaternary alluvium and the Brule. A selection of that discussion follows while the tabular data occurs on page 128 of the referenced document and in the Appendix to this report:

> "The water in the sand and gravel is uniformly of moderate hardness, averaging about 277 parts per million and ranging from 126 to 345 parts per million. In addition to the calcium and magnesium bicarbonate, which make the water hard, water from the sand and gravel contains widely varying quantities of sodium and potassium, moderately large amounts of sulphate, and small amounts of chloride. Those samples show great uniformity, not only in type of water but also in the quantity of the various important constituents with the exception of the sodium and potassium."

> "Most of the samples from wells in the Brule formation are of a similar type to those from the sand and gravel, that is, they are moderately hard, calcium and magnesium-bicarbonate waters, although as a whole, they are somewhat less highly mineralized." Samples appeared bimodal in hardness with clusters varying from 188 to 273 and from 44 to 112 parts per million of hardness. These latter were of sodium bicarbonate water. "The bicarbonate in the samples from wells in the Brule is rather uniformly moderate in amount . . . The amount of sulfate is low to moderate . . . it tends to be lower in the softer waters than in the harder" (USGS WSP 943, p. 127).

USGS Hydrologic Investigations Atlas HA61 (1962) contains maps of prevalent dissolved-solids concentrations, prevalent chemical type, and average sediment concentration of rivers of the conterminous United States. Rivers in the vicinity of the Lockwood Corporation site probably have dissolved-solids concentrations between 340 and 700 parts per million, calcium-magnesium sulfate-chloride chemical type, and an average sediment concentration of 280 to 1950 parts per million.

Resources Atlas No. 3, a CSD and USGS joint publication (1978) includes chemical parameter maps for several variables. It indicates that the Lockwood Corporation site has groundwater with 501-1000 milligrams per liter dissolved solids, 181-360 milligrams per liter hardness ($CaCO_3$), greater than 50 milligrams per liter sodium plus potassium, greater than 300 milligrams per liter alkalinity (as $CaCO_3$), greater than 100 milligrams per liter sulfate, 11-100 milligrams per liter chloride, 0.6 - 1.0 milligrams per liter fluoride, greater than 50 milligrams per liter silica, greater than 330 micrograms per liter boron, 0-100 micrograms per liter iron, 0-50 micrograms per liter manganese, 0-10 micrograms per liter selenium, 0-6 micrograms per liter phosphorus, less than 10 milligrams per liter nitrate, and none of the following trace constituents were known to exceed EPA drinking water standards: arsenic, copper, cadmium, lead, zinc, or silver.

USGS WSP 2179 (1983) contains tabular surface water chemistry for particular sampling stations along streams within particular drainage basins. The Lockwood Corporation site is within the northwestern extremity of the North Platte River Basin. Two sampling stations are close to the site: 06680800, on the Tri-State canal 3 miles northeast of Scottsbluff; and 06681300, on the Mitchel-Gering canal, 2.8 miles southwest of Gering. Tabular data occurs on pages 56-59 of the referenced document and in the Appendix of this report.

USGS WSP 2245 (1984) contains chemical parameter maps for several variables as well as statistical summary tables for chemical parameter concentrations in Holocene/Pleistocene and Tertiary aquifers. The chemical parameter maps indicate that the Holocene and Pleistocene aquifers at the site contain water with 251-750 milligrams per liter dissolved-solids, 26-75 milligrams per liter calcium, 101-300 milligrams per liter alkalinity (as calcium carbonate), and more than 100 milligrams per liter sulfate. Similar maps for Tertiary aquifers indicated 251-750 milligrams per liter dissolved-solids, 26-100 milligrams per liter calcium, 101-300 milligrams per liter alkalinity (as calcium carbonate), and more than 100 milligrams per liter sulfate. The tables referred to above occur on pages 17-18 and 28-30 of the referenced document and in the Appendix of this report.

Although USGS Water-Data Report NE 84-1 contains tabular chemical data for surface-water-quality stations as well as surface-water-gaging station data, no chemical data within the report can reasonably be attributed to groundwater at this site. Surface-water-gaging station 06681500 is along the Gering Drain within 3/4 miles of the site, yet only quantitative information is recorded (p. 74). Incidentally, this record shows an annual low discharge of about 24 cubic feet per second in March, rising to more than 170 in June, declining and then rising to almost 190 cubic feet per second in September. Page 339 gives only piezometric data from USGS Observation Well 415325103392801, about 6 miles NNW of the site; however, search of the files of the UNL Conservation and Survey Division revealed that groundwater samples had been taken 11/17/70 and 6/22/77. Unfortunately, drilling logs for this well could not be obtained; it is therefore not known which units were completed in this well. Copies of these analyses are included in the Appendix to this report.

Search of the chemical data from municipal water supply wells in the files of the Nebraska Department of Health yielded 3/78 sampling results for four Gering city wells. These are certainly some of the municipal wells in Section 35, T. 22N, R. 55W, but specifically which four could not be determined as neither location nor well designation were recorded. Thus probably include both Qual and Brule completions within each well. Copies of these records appear in the Appendix to this report.

Comparison of all of the above-cited documents with respect to groundwater chemical parameters yields the following conclusions. Inconsistency exists in estimates of total dissolved solids: there is recorded a range of 251-1000 mg/liter. Estimates of hardness (as $CaCO_3$) vary widely: 126-360 mg/liter. Alkalinity (as $CaCO_3$) is inconsistently estimated. The recorded range is 101-380 mg/liter. The range of recorded pH is 7.3 - 8.1, higher in wells completed in the Brule. Nitrate concentration varies widely, from 4.2 to 38 mg/liter. Sulfate concentration is recorded as 101-280 mg/liter. Bicarbonate ion concentration range is reported as 255-462 mg/liter, lower in surface water. Recorded Na, and Na plus K, concentrations vary widely, from 84-239 and 51-212 mg/liter, respectively. Reported concentration of Na in surface water is relatively lower. Calcium concentrations recorded are slightly inconsistent, with a range of variation of 26-102.5 mg/liter. Iron concentration varies from 0 to 100 micrograms/liter, Mn from 0 to 50, F from 0.0 to 1.0, B from 175 to more than 330 (with surface water concentrations reported being relatively low), Se from 0 to 10 and P from 0 to 8.8 micrograms/liter. Chlorine concentration reports are inconsistent, with a range of 11 to 238 mg/liter. Magnesium concentrations are recorded as varying from 16 to 22 mg/liter, and Silica concentrations from 51 to 58 mg/liter.

III. Regional Geologic Hazard Assessment

A. Earthquake

The Seismic Risk Map of the United States indicates that the Lockwood Corporation site is within a Zone 1 region. This is defined as an area where earthquakes of Modified Mercalli Scale intensities V and VI have occurred, regardless of frequency. Intensities V and VI are defined as follows:

> Intensity V (Richter Scale magnitude 3.5 - 4.125) - "Felt indoors by practically all, outdoors by many or most: outdoors direction estimated. Awakened many or most. Frightened few, slight excitement, a few run outdoors. Buildings trembled throughout. Cracked windows, in some cases, but not generally. Overturned vases, small or unstable objects in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls or swung them out of place. Opened or closed shutters, abruptly. Pendulum clocks stopped, started, or ran fast or slow. Moved small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees, bushes, shaken slightly."

> Intensity VI (Richter Scale magnitude 4.125 - 4.7) - "Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many ran outdoors. Awakened all. Persons made to move unsteadily. Trees, bushes, shaken slightly to moderately. Liquid set in strong motion. Small bells rang,

church, chapel, school, and so forth. Damage slight in poorly built buildings. Fall of plaster, in small amounts. Cracked plaster somewhat, especially fine cracks in chimneys in some instances. Broke dishes, glassware, in considerable quantities also some windows. Fall of knick-knacks, books, pictures. Overturned furniture in many instances. Moved furnishings of moderately heavy kind."

An earthquake of intensity IV - V is recorded as having occurred on August 8, 1933 at latitude 41 50' 02" north and longitude 103 40' 02" west, which is about 2 miles NW of the site studied. Docekal (1970) reports the event as follows: "An earthquake (intensity IV - V) centered near Scottsbluff, Nebraska, shock buildings over a wide area of western Nebraska and eastern Wyoming (on August 8, 1933). Henry, Nebraska, reported a loud explosion."

Review of the narrative descriptions of the different intensity categories within the Modified Mercalli Intensity Scale of 1931 suggests that surface impoundments in general would probably not be comprised in any way until Intensity VIII was reached. This intensity has a Richter Scale magnitude equivalent of 5.35-5.98. Inspection of the Bouguer gravity anomaly map does not show any conclusive correlation between the epicenter location and any anomalous crustal feature. The presence of metamorphic as well as igneous rocks at the Precambrian surface is not reassuring in terms of hazard due to major earthquakes: mafic and metamorphic rocks generally indicate weaker crustal areas. But detailed evidence of Precambrian lithology in close proximity to the site is lacking.

It is interesting to note that Swinehart et al (1985) identify a structural hinge in the surface of the base of the Cenozoic in the vicinity of the present North Platte River valley, in close proximity to the site. Figure 22 of the paper cited above indicates the location of the North Platte River hinge an arc sweeping from the NW to ESE, concave toward the NE with steep NE dips SW of the hinge and gentle E dips to the NE. This hinge roughly parallels the Chadron Arch. Chadron Formation paleodrainage through this site was toward the SE, similar to today's drainage; however, subsequent Gering Formation and Ogallala Group paleodrainages were substantially toward the east, obviously having been affected by movement along the hinge that deflected the SE-trending drainage toward the north.

B. Flood

The FIRM Flood Insurance Rate Map (2/15/79) indicates that the site is within a Zone C area, an area "of minimal flooding". It is estimated by FIRM that not even a '100-year flood' would inundate the site; however, the Corps of Engineers, in their 6/27/86 comment on the Lockwood closure and post-closure plans, indicated that:

"The possibility may exist, however, for a flood hazard that could result from heavy rainfall in the immediate area which would produce runoff in excess of storm sewer and local drainageway capacities. Any flooding that would result from this phenomenon would probably be quite localized and shallow. Detailed definitions of this hazard would require a site specific investigation."

D. Adequacy of Site Characterization

I. Stratigraphy

Lockwood addresses site stratigraphy in two documents: the Status Report on Hydrogeologic Investigation (8/29/84) and the Hydrogeologic Investigation and Remedial Action Plan (11/9/84). The former document constitutes preliminary conclusions of the latter; all of the issues that it addresses are later subsumed in the more detailed discussion of the Hyd. Invest. and so only that document will be reviewed. Geology and hydrogeology are presented on pages 5-10.

A sketch of the general stratigraphy of the site occurs on page 5. More details of lithology, basinal stratigraphy, tectonic activities concomitant with the deposits, strict temporal framework, and depositional models could have been presented.

The review of the Brule on page 6 is adequate. Stratigraphic detail is lacking. The approach tends toward conceptual homogenization of the unit by stratigraphically vague statements such as, "much of the formation . . . ." or "part of the Brule . . ." It would be more useful to narrow the comments down to specific units within the Brule and then discuss what portion is represented immediately beneath the site.

Comments pertaining to the alluvial deposit overlying the Brule are accurate. The age of the deposit could have been mentioned, as well as the published petrographic information and the common designation of the depositional model: braided stream.

Figure 2, a geologic cross-section, appears adequate. It does lack a legend and the Brule/Chadron contact is problematical.

Lockwood's treatment of the stratigraphy underlying the site, although not detailed, is adequate. Absent is any discussion of the overlying soil types and chemistry. The alkaline nature of soils, aquifer sediments, and the Brule ought to have been emphasized as it is of critical interest with a characteristically acidic waste. It is mentioned on page 6 that part of the Brule appears to be loessal and also that this formation is generally calcareous, though the two concepts are presented as if unrelated. Lowry's application of "piping" (Parker, 1963) to the White River Formation is alluded to, yet his conclusions are not considered three pages later in discussion of transmissivity in the Brule.

The division of this site profile into three "units" (sentence 2) is problematical. The first unit is defined as 7-10 feet of "silty and sandy clay", yet most of the boring logs indicate that silty sand and sandy silt are much more dominant in this interval. One well (B-7) actually notes silty gravel at a depth of 5 to 15 feet. Cross-sections A'-A" and B'-B" indicate that Unit 1 is largely dominated by SM, defined on the Unified

Soil Classification System as "silty sands, sand-silt mixtures." It is later noted (page 8, paragraph 1, sentence 5) that Lockwood added 2 to 4 feet of "fill" over the entire site of both impoundments prior to construction. This fill is also noted on the two cross-sections, which, along with the boring logs, describe it as SM. Inclusion of this fill along with the natural (also dominantly silty sand - SM) alluvial deposit in the same unit clearly indicates that HWS's unit criteria are not genetic. Unit 2 is defined as "a sand and gravel unit 10 to 12 feet thick with some interbedded silty and sandy clays." Discrimination of this unit from Unit 1 is valid, the primary distinguishing characteristic obviously being the occurrence of gravel. It is speculation on the part of this author, but perhaps Unit 2 represents the Early Pleistocene while Unit 1 (minus "fill") represents the more moderate Recent climatic conditions. Unit 3 is here defined as "a semi-consolidated silty clay constituting the weathered surface of the Brule Formation". This particular reference appears not to favor the visualization of an autochthonous siltstone conglomerate erosional lag deposit (see McLaughlin, 1948, p. 13). The only indication of weathering apparent in the Brule encountered in the borings was coloration: brown to yellowish brown. The innate permeability of this unit, sans piping (or fractures), is probably as low as 0.2 gpd/ft^2 (Rapp et al, 1953) "very low" to "low" relative permeability according to the U.S.C.S. It is, however, quite probably piped or fractured.

Lockwood (p. 7, sentence 4) equates alluvium with unit 2 and alleges that it is unconfined. This author contends that unit 1 (minus "fill") is also predominantly alluvium, the remainder being probably colluvial. It is apparent that this unit is unconfined, there being no overlying aquitard and a water table being associated (the water table occurs within Unit 1). Lockwood goes on to state that the Brule "is probably semi-confined ("artesian" setting) with impermeable zones or beds within the Brule likely acting as confining beds." Sentence 6 indicates that local flow directions are effected by canals, lagoons, etc. It also makes reference to seasonal fluctuations in flow direction. At least one annual cycle of monthly piezometric data would be necessary to justify this last statement.

Page 8, sentence 2 refers to "research of available literature and analysis of topographic maps", yet does not specify the sources. It indicates that seeps and marshy conditions prevailed at the site at least seasonally, yet the most current topographic map (1963), the photorevision of which (1976) indicates the site buildings, does not show marsh or spring symbols near the site. it is assumed that Lockwood refers to the change of soil type that is indicated on the 1:20000 scale detailed soil map sheet of the county soil survey (1968). This is a break between a silt loam and a "silt loam, wet variant" wherein a perched water table is common. Such a condition is not in evidence immediately at the site, however. The reference to the addition of "fill" (sentence 6) is the first occurrence of such information.

Sentence 2 states that "hydraulic conductivity can be estimated by visual inspection of the samples . . ." This is a very uncertain approach, the tendency being to down-play negative skewness and exaggerate kurtosis.

yielding a higher porosity than real, and thus a higher hydraulic conductivity.

Sentence 3 used the word 'determined', yet does not specify which of the two approaches alluded to were used. This question tends to dampen one's acceptance of the values of hydraulic conductivity presented in Table 1. Converting the values given to cm/sec (multiplying by 4.7148×10^{-5}) and checking the expected ranges with those defined as expected under the U.S.C.S., indicates that the values for the fill are reasonable; those for CL may be excessively low at the low end; those for SM are reasonable; those for GM may be excessive at the high end, and those for SP are reasonable. The reader will note that we are actually checking the application of the U.S.C.S. terminology with the given data, not the reverse.

Sentence 2 implies that contoured piezometer maps were constructed, however none are presented. Sentence 3 is apparently a prediction as no piezometric data over time was, or is, available. It is uncertain whether Lockwood intends to refer to the natural groundwater or K062/D002 seepage from the lagoons. The sentence also implies that the large quantity of seepage fluid overwhelms the low gradient and thus disseminates even against that gradient. This is probable, but could have been more clearly stated.

The numerical example of transmissivity calculation for B-1 is poorly presented; the origin and nature of the numbers should have been specified. Which value is thickness? Which is hydraulic conductivity? Even with Table 1 and the boring drillers' log in hand, the calculations are unclear.

Paragraph 4 gives a transmissivity range for the "alluvium in the vicinity of the acid pit". Does this include both Units 1 and 2 or only Unit 2, which was previously referred to as "the alluvium" apparently in an exclusive sense (page 7, sentence 4)? The range given is 300 to 600 gpd/ft. How was this calculated? Is it the range derived for all of the borings or only those "in the vicinity of the acid pit"? What is actually meant by this phrase? It is assumed by this author that "fill" is excluded from this calculation, since it is not alluvium but is artificially redeposited. Transmissivity of vadose zone sediment (part of Unit 1) is technically to be included, as 'alluvium" and not 'alluvial portion of the aquifer' is referred to. In short, this range may be accurate, but the technical questions render the statement incapable of verification. Furthermore, the number and exact position of samples used to set up the generalizations of Table 1 have not been presented.

Paragraph 5 (and paragraph 1 of page 10) considers the transmissivity of the Brule, yet published data for thickness and hydraulic conductivity of the Brule are not discussed. Instead, Lockwood/HWS applied the equation of U.S.G.S. Water Supply Paper 1536(i): T = 2000 x specific capacity.

Application of this equation is singularly unsuited to the Brule (V. Souders, personal communication, 9/22/86). The Brule is noted for its low innate hydraulic conductivity and high probability of secondary permeability (due to piping, according to Lowry). There is also, according to Lowry (1966, p. 218) and McLaughlin (1948, p.13) a high probability that high-yielding wells allegedly completed in the Brule actually yield from the overlying alluvium.

With respect to page 10, paragraph 1, sentence 4: is this an indication of permeability, or simply the vertical frequency and effectiveness of piping/fractures?

With respect to sentence 2, this effectiveness, in terms of gpd/ft^2 hydraulic conductivity, could be estimated. Sentence 4 states that the liner of Cell #2 rests upon "complex but generally fine-ground alluvium." The alluvium as a whole is not fine-grained. It is dominantly SM, and even includes GM, which is not fine-grained. If Lockwood/HWS mean to indicate the sediment most immediately beneath the site, that is fill and described as SM. Boring logs do not indicate an extensive clay strata immediately beneath the fill.

Sentence 7 includes three stratigraphic conclusions. The first was that "a degree of protection exists for the alluvial aquifer, as hydraulic conductivities are somewhat lower in the areas with higher silt and clay content." This is a very weak observation. According to the Closure Plan (9/6/85, p. 5) the impoundments were active from 11/72 to 6/84: 146 months. Each month one of them received two batch discharges each of at least 5-8,000 gallons for a total of 1.40 to 2.24 million gallons. Some one and a half to two and a quarter million gallons of spent pickle liquor did reside in these impoundments. It is impossible now to accurately reconstruct how much water evaporated, but evaporation only served to residually concentrate the heavy metals and decrease the pH. Seepage from the lagoons was considerable. It has already been established that both impoundments are underlain by SM fill, with a range in hydraulic conductivity of 0.5 - 10 gpd/ft^2. This does not constitute "protection".

The second conclusion was that "complex distribution of the sandy zones could allow highly variable recharge rates; that is, more infiltrating 'recharge' water would flow through some parts of the subsurface than others". This is true; this is an effect of the lensatic inhomogeneity of a braided stream deposit.

The third conclusion was that "because of these complexities, flow paths to the alluvial aquifer could be extended somewhat in length, with longer travel times resulting." This is poor reasoning. When the fluid encounters the water table, it enters the aquifer. The water table occurs at a depth of from 8 to 10 feet at this site in the winter time and is probably higher during irrigation season. From 2 to 4 feet of this depth is surface fill, relatively homogenized SM. Therefore the vadose zone beneath fill is some 4 to 8 feet in depth. This is primarily SM, the hydraulic conductivity of which may be as high as 30 gpd/ft^2, or 5.22 x 10^{-5} ft/sec. For water to percolate 4 feet through such material could take less than 22 hours.

The two cross-sections that accompanied the Hyd. Invest. (sheets 2 and 3) are the graphical representation of Lockwood's stratigraphic study. The following are departures from TEGD guidelines, which, while they do not have the strength of regulations, do suggest some room for improvement in an otherwise useful and adequate stratigraphic presentation.

1) There is no key to the geological symbols employed.

2) T.D.'s are not labeled.

3) The standard water table symbol is not used.

4) Hydraulic conductivity values and sample points are not noted.

5) The designation "I.A.D." is employed, but nowhere defined.

6) Chemical parameter values from groundwater sampling do not appear.

7) No attempt was made to overlie a potentiometric cross-section.

8) No symbol was employed to designate, nor does the chosen classification account for, carbonate clasts. These are frequently noted in boring drillers' logs and are obviously relevant considering the nature of the contaminant.

9) No mention is made of environments of deposition.

10) The main distinguishing criteria between Unit 1 and Unit 2 (the first occurrence of pebbles) is not discriminated in the U.S.C.S.; therefore, this was clearly a poor choice of classification to employ.

11) Inaccurate "lumping" of U.S.C.S. designations took place between the drillers' logs and the boring traces on the cross-sections.

12) For the most part, the facies discriminated with U.S.C.S. designations are not correlated.

13) The cross-sections treat the Brule Formation as a "bedrock", even using the standard bedrock symbol, although evidence indicates that this is part of the uppermost aquifer.

14) Brule Formation secondary permeability (piping/fractures) is not noted.

15) No updated cross-sections were submitted accounting for the ten (10) monitoring wells completed 10/10/85.

II. Definitions of the Uppermost Aquifer

Lockwood/HWS appears to consider the uppermost aquifer as limited to Unit 2. The 7/22/85 submittal contains the statement, "All fluids entering site soils and/or fill soils ultimately drain into unit 2" (page 3, #3). The Hyd. Invest. (11/9/84) contains the statement, "Groundwater in the alluvium (unit 2) is unconfined . . ." the Preliminary Hydrogeologic Investigation (8/29/84) contains the statement, "Unit 3 acts as an aquitard at the site . . ." (page 2, paragraph 2, sentence 3). These statements lead this author to believe that Lockwood/HWS considers Unit 2 to be the uppermost aquifer, exclusively.

On the other hand, the Hyd. Invest. contains two cross-sections, both of which clearly indicate a water table within Unit 1. The conclusion is that the lower portion of Unit 1, beneath the water table, is legitimately to be considered aquifer. With respect to the Brule, the Preliminary Hydrogeologic Investigation and the Hyd. Invest. both discuss groundwater in the Brule, thus identifying it as aquifer, though not the uppermost aquifer. As quoted above, Unit 3 is considered by Lockwood/HWS to be an aquitard. There is reason to believe that Lockwood/HWS consider it to be distinct from the Brule generally. It is usually referred to as the weathered surface of the Brule (Prelim. Hyd. Invest., page 2, paragraph 2, sentence 1; Hyd. Invest., page 7, sentence 2; etc.). Sentence 1, paragraph 3, page 2 of the Prelim. Hyd. Invest. actually distinguishes the two: "Groundwater occurrence at the site is . . . semi-confined to confined in the Brule Formation underlying the weathered Unit 3".

It is apparent that much of what Lockwood/HWS defines as Unit 1 is part of the uppermost aquifer.

No evidence has been presented which indicates the presence of an aquitard between the Brule and the overlying Pleistocene to Recent braided stream deposits, and it is apparent that the Brule itself is an aquifer. It is therefore this author's suggestion that the Brule is to be considered part of the Uppermost Aquifer. However, no information suggests that the groundwater contamination extends into the Brule and the alkaline nature of the Brule would mitigate any potential impacts in any event. Therefore the question of monitoring the Brule is actually moot.

III. Background Groundwater Chemistry

Lockwood/HWS's determination of background groundwater chemistry is reviewed in the Hyd. Invest. (11/9/84), section VI Groundwater Quality, and Appendices II and III.

Lockwood/HWS's review of published information was apparently limited to USGS WSP 943 (1946) and a compilation of the Nebraska Department of Health municipal well samples.

Discussion of published data is quite meager. There is no discussion of which wells in Hyd. Invest. Table 2 are in close proximity to the site, nor of which intervals each is completed in.

Appendix II is comprised of data provided to Lockwood/HWS by NDEC, which sampled the three closest wells to the site. All three are in a downgradient direction with respect to the regional groundwater flow. The city well, registered as "Gering Industrial Well No. 1 (6/29/77), Registration No. G-56972 (CSD, State of Nebraska Well Registration), a.k.a. "Gering municipal well #6" (NDEC Investigation Report 6/20/84: page 2, paragraph 4, sentence 1) and "City of Gering's Well 77-1" (Hyd. Invest., page 11, paragraph 4, sentence 1), and "76-1" (Hyd. Invest., Table 3), was sampled during 10/77 and on 4/18/84. Unfortunately, the only overlap of sampling parameters between these two sampling and analysis events is in pH, which changes from 8.1 to 7.5.

10/77		4/18/84	
pH	8.1	pH	7.5
TS	968	As, tot.	.014
Fe	0.0	Pb, tot.	.013
Mn	0.0	Zn, tot.	.012
F	0.93	Cr, tot.	.006
Alk	396	Cd, tot.	<.002
Hard	132	Ag, tot.	<.0005
Ca	38	Se, tot.	<.005
NO_3	5.2	Cr VI, tot.	<.004
Cl	120	As, E.P. Tox	.011
SO_4	191	Cd, E. P. Tox	<.002
Na	350	Cr VI, E. P. Tox	<.003
		Pb, E. P. Tox	.012
		Se, E. P. Tox	.005
		Ag, E. P. Tox	<.0005

Units are in mg/l, except in the case of pH.

This well is estimated as being 1500 feet roughly NNW of the impoundments.

Two private wells, called A and B, were also sampled on 4/18/84. They are approximately 2600 and 2000 feet roughly NNE of the impoundments, respectively.

Although Lockwood/HWS reported sampling the municipal well during 8/84 for chromium, no results were presented.

Table 4 includes background chemical data. A range of 1,200 to 1,300 umhos/cm specific conductance is listed but no reference is cited. This concentration appears high. No iron concentration is given, while published data indicate 0.0 to 0.1 ppm.

Lockwood/HWS's analytical results from the 11/7/85 sampling event on the ten RCRA assessment monitoring wells are compared with background concentrations in the 3/7/86 entry in section B.

IV. Hydraulic Characteristics of Each Formation Present

Lockwood/HWS presents reservoir parameter data on pages 8 to 10 of the Hyd. Invest. (11/9/84). This data is reviewed in detail in section D. I of this report.

E. Assessment Monitoring System

I. Design

Lockwood requested NDEC guidance with respect to monitoring well location and design on 5/21/84. Lockwood/HWS first proposed installation of "four (4) groundwater monitoring wells fully penetrating Unit 2" on 8/27/84. This recommendation was reiterated in the Hyd. Invest. (11/9/84), which also proposed a dual use for the wells: monitoring and interceptor wells, the latter to extract acid-leaching-mobilized pollutants. A well design diagram was included.

Well designs were adequate. Gravel pack design and screen slot choice were particularly well done. The following suggestions for improvement are noted when reviewed in light of the criteria of Ch. 3 of the TEGD:

√ 1. No PVC cap is provided to cover the open wellhead within the lockable surface protection casing.

2. The surface easing extension is not vented.

√ 3. The bit size/hole diameter is not specified.

√ 4. Gravel pack annular thickness is not specified.

√ 5. There is no bentonite annular seal (pellets or powder) between surface cement and gravel pack.

6. The depth of the surface cement annulus is not specified.

7. No dimension is specified for the extension of the gravel pack above the water table.

8. The water table profile provided is not labeled. Is this max., min, annual average, or anticipated level at a particular period anticipated for the well installation?

9. No 'rat hole' is provided for.

√ 10. Drilling method is not specified.

11. Assuming that the mud rotary method was intended, no details of completion fluid type (density, viscosity, fluid loss, conductivity, chemical composition of additives, quantity, lost circulation contingency additives, etc.) were provided.

12. No TD rationale were specified. How deeply will the Brule be penetrated?

13. No engineering rationale for development method, rate, and duration were provided.

14. No formation grain size histograms and graphical derivation of gravel pack design and screen size choice were provided.

√ 15. No details on slot geometry (length, cross-sectional shape, and frequency or 'density') and slotting method (hack-sawed or factory-machined) are specified. If the method was to be factory-machining, would this be sonic-welding or cutting?

16. No source and designation(s), with class percentages, of the gravel pack mixture is provided.

17. Is the Certa-Loc 'end cap' (sic) bull plug threaded? If so, what is the thread 'density', width and geometry? Are these equipped with butyl o-rings? If not threaded, are they sonic-welded or glued (with what compound)?

18. The composition of the surface cement is not specified. Does this contain powderized bentonite?

19. The Certa-Lok fitting casing joint is apparently threaded, yet thread specifications ('density', width, and geometry) are not noted. Are butyl o-rings provided?

√ 20. What is the petrology of the gravel pack material?

21. What were the selection criteria for casing diameter?

22. Are the wells to be provided with dedicated bailers?

It is noted that the wells, as designed, are to be completed at the base of the braided stream deposit with a minimum of ten (10) feet of open screen.

The 6/21/85 NDEC response to Lockwood's Hyd. Invest. (11/19/84) and Supplemental Report (1/7/85) noted that the proposed monitoring network was minimal and not appropriate to a site where groundwater contamination had already been detected. It was designed to meet the detection monitoring system requirements of 40 CFR 265.91(a) rather than the assessment monitoring requirements of 40 CFR 265.93(a). NDEC suggested ten (10) specific well locations.

The 7/17/85 Lockwood/HWS response proposed ten wells: eight of them of 4-inch diameter and two of 8-inch diameter. the latter to function as recovery wells for a pump test and interception wells, presumably for possible later remedial action, as well as functioning as monitoring wells. The 4-inch diameter wells would serve as piezometers for the pump test as well as monitoring wells. The submittal included a well design diagram (Figure 2) identical to Figure 6 of the Hyd. Invest., but including a hole diameter specification of 14 inches minimum (thus a 3-inch annular thickness for the gravel pack). It is assumed that the 4-inch wells would have had a scaled-down bitsize/hole diameter, but this was not stated.

NDEC approved well installation on 8/20/85, recommending that the pump test not be conducted unless subsequent data from groundwater monitoring of these wells should warrant it.

On 10/3/85 NDEC advised Lockwood/HWS that "specific grain sizing documentation for the filter pack is requested." It also stated that ". . . soil samples from the borings should be tested. . .", which implied that well installation should be by auger.

Well installation occurred on 10/7 - 10/85. This author was present on site from 10/8 - 10/85. The following observations were made:

> At approximately 0830, October 7, I contacted Mr. Roy Dugan of Lockwood Corporation who informed me that drilling would commence shortly on the proposed 10-well drilling round.
>
> I arrived on site at 0730, October 8, finding a standard 2000 ft. certified truck-mounted rotary rig with water and service trucks. The service trucks contained approximately 40' of 6" and 160' of 4" I.D. Schedule 40 "NSF Pro" PVC casing, 20' of 6" and 80' of 4" ID Schedule 40 "NSF Pro" PVC factory-slotted, louvered 10/1000" screen. Pull plugs were sonic-welded on the 6"; all joints were "Certain-Teed" (with flat threads and "O" rings). No pipe dope, PVC primer or PVC solvent cement were present. No bow spring or broad-fin bull plug centralizers were present. Gravel pack material was stockpiled in a truck bed - a very well sorted, medium grained fluvial sand, sub-rounded, approximately 85% Qtz, 10% alkali feldspar, 5% mafics. The trucks also contained sacks of cement and "Poly Gel" (a drilling mud containing sodium bentonite and a strong caustic commonly used in shallow, unconsolidated formation oil wells; it produces a thick borehole mud cake).
>
> The presence of a rotary rig and "poly gel" were causes for concern. NDEC had specified in previous correspondence that soil (sic) samples be taken during drilling. This implies the use of an auger, which yields chemically undisturbed samples. The addition of drilling mud, particularly a caustic mud, increases pH and also

adsorbs metal cations: low pH and high heave metals concentration are the anticipated measureable effects of K062 contamination. In short, the method employed on well emplacement would tend to invalidate the chemical monitoring results.

The crew and HWS consultant representative (Don Kuhlman, P.E.) arrived at 0920. I expressed my concerns to him and he indicated that of the two wells drilled on October 7, the 4" I.D. well was drilled using fresh water and the 6" I.D. well was drilled using "poly gel". I informed him that the chemical results from the 6" I.D. well would have to be considered suspect and that later review of this data by NDEC may result in a request for redrilling. I recommended use of fresh water from this point on and sodium bentonite only if borehole sloughing prevented completion. I also indicated that hollow-stem augering would have been a superior installation technique as it would not have required the bentonite contingency.

Kuhlman called his "poly gel" supplier who concurred with my recommendation. Drilling proceeded using fresh water on two wells at which point it was apparent that formation sloughing compromised reservoir continuity adjacent to the wells. Having acquired a supply of sodium bentonite, drilling on the 9th and 10th proceeded without problems; the final monitoring well was completed by 1900, October 10.

HWS consultant had made no provision for decontamination of drilling equipment or submersible development pump between wells. The gravel pack was shoveled into place without use of funnel and tremie pipe to protect the purity of the pack from up hole formation sloughing. Cement was poured directly on the gravel pack. Casing lengths from T.D. to final sawed top were recorded only at my insistence. There was no engineering rationale for development pumping rate or duration.

As I had requested previously, HWS had histograms of formation boring samples and the proposed gravel pack material on site. Evaluating these according to the procedures of: 1) U.S. Department of Interior Ground Water Manual and 2) Johnson Division U.O.P. Groundwater and Wells, it was apparent that the engineering design of gravel pack grain size parameters and screen slot size was sound.

II. Placement

Lockwood/HWS initially (8/27/84) proposed a four-well monitoring system, but delayed proposal of well locations until submittal of the Hyd. Invest. (11/9/84), Sheet 1 of which proposes one well in the extreme southwestern corner of the plant property about 175 feet SW of the erosion pit in Cell #2, one about 163 feet NW of this same point, one about 200 feet SE, and one about 630 feet NNE to due north.

The reviews of the Hyd. Invest. by an NDEC hydrogeologist (11/21/84) and soil scientist (12/10/84), as well as the 6/21/85 formal response by

NDEC to the Hyd. Invest. and Supplemental Report. cited high (0.10 mg/l) chromium and lead (0.05) concentrations of Table 4. as well as various apparent peculiarities in mg/l data presentation and interpretation. Seven of the ten monitoring well locations suggested by NDEC in the 6/21/85 review are in close proximity to previous boring locations that yielded these high contaminant values in groundwater samples (B-1. 2, 6. 7. 8. 11. 13, 14. 15. and 16). The other three locations are further north, and regionally downgradient. of the site area previously investigated.

Lockwood/HWS's revised proposal of 7/22/85 was also for ten monitoring wells. six locations being essentially identical to NDEC's. Lockwood/HWS preferred to shift one of NDEC's suggested regionally downgradient locations approximately 200 feet east to a position just within its own fenced property boundary. Two 8-inch diameter monitoring/interceptor wells were proposed on opposite sides of the impoundments with a 4-inch diameter monitoring well within 30 feet of each. presumably for convenient piezometric data locations for the anticipated pump test also proposed.

These locations were reviewed in a telephone conversation of 7/25/85. between Lockwood and NDEC. NDEC indicating that it did not currently advise the pump test and so several of the Lockwood/HWS proposed locations would largely produce replicate information. The Lockwood/HWS locations were approved by NDEC in a telephone conversation and in writing on 8/20/85. Wells were installed at these locations 10/7 - 10/85.

The existing wells virtually surround the impoundment site in a rough in-echelon pattern. Only the southwest direction (regionally upgradient) is uncovered. Most of the wells were intentionally situated to monitor localities that were previously indicated to have high contaminant concentrations in groundwater samples.

The obvious deficiencies of the current monitoring system are: 1) lack of coverage in a regionally upgradient direction (a moot point considering the likelihood of seasonal fluctuations in local groundwater flow direction and also the assumed continued availability of the Gering municipal well 77-1/76-1/#6. etc., and also the two previously identified private wells A and B): and 2) lack of deeper monitoring of the thick underlying Brule formation. which is generally acknowledged to have aquifer potential.

QA/QC Sampling and Analysis Program

A. Sample Collection Procedures

I. Initial Observations

This author and Mr. Bill Imig. an NDEC Technical Services Section sampling specialist. arrived on site at 0930 hrs: 4/10/86. The temperature was about 70^{o}: winds variable but picking up to about 10-15 mph, dropping to about 10 mph and gusty by 1200 hrs. Clouds were scattered cumulus and high cirrus.

This author completed a brief inspection of the impoundment area. noting the following observations:

1. None of the surface cement pads around lockable steel surface protective casings were undercut by erosion.

2. None of the lockable steel surface protective casings (painted gray) had padlocks. Well MI-1 had a very loose metal cap.

3. Each of the ten monitoring wells was surrounded with a triangular metal framework fence. approximately 1 m to a side and 1 m tall. painted silver. upon one corner of which was wired an aluminum socket that supported a red plastic flag. These flags extended to about 2 m off the ground and markedly improved the visibility of each monitoring well.

4. None of the wells was labeled with its numerical designation.

5. B-10. one of the borings in the initial auger drilling round. located about 7 feet south of monitoring well M-4. is open. unplugged. and dangerous. It has a surface diameter of about 7 inches.

II. Equipment Utilized.

A. The following equipment were utilized by HWS/Enviro Services (sub-contractor).

1. Two Suburban vehicles. one containing a generator (Powermate PM 4500 electric generator for the submersible pump). and a large distilled water container.

2. A 50-ft coiled aluminum tape.

3. A 20 liter deionized water squeeze bottle.

4. Rubber gloves.

5. Five-gallon plastic bucket to discharge purged well fluid into.

6. A submersible pump: A 12-50 Aeromotor S.S. w/inert plastic impellers (made by Aeromotor Pumps and Well Systems. Conway. AR 72032). with about 70 feet of electric extension cord. and about 50 ft. of rope (to tie from the well-guard fence to the pump).

7. A 1 1/4" diameter plastic hose, by Klearcop, attached to the submersible pump and extending about 35-40' up to the bucket.

8. A Specific Conductivity/pH meter (Markson Science, Inc.), temperature compensated, photovolt. The S.C. was calibrated at 720 and 2000 micro mhos/cm @ 25^{O} C (calibrated in the lab prior to the site visit and checked only with the 2000 solution in the field.

9. 500 ml Sargent-Welch standard buffer solution pH 10.0, color coded blue, 5-30141-15C, pH 10.18 @ 10^{O}C, 10.11 @ 15^{O}C.

10. 500 ml Fisher Scientific certified buffer solution pH 7.00 + 0.01 @ 25^{O}C color coded yellow, 50-B-107, pH 7.7 @ 10^{O}C, 7.05 @ 15^{O}.

11. A 1m-long clear Teflon bailer with ball value, plastic braided cord (about 50 ft.) rolled on a spindle.

12. 5"-long, plastic, disposable pipettes.

13. Clear plastic cups: 2 for each well filled from the bailer for the S.C./pH meter: one cup containing each buffer (2); one cup with S.C. calibrating fluid (2000 micro mhos/cm @ 25^{O}).

14. 500 ml clear plastic jars with Teflon-ringed lids (4/well).

15. 500 ml brown glass jars with Teflon-ringed lids (2/well).

16. 40 ml "septa" vials, clear glass (2/well).

17. 2 large, ice-filled coolers.

18. Glass jar of HNO_3.

19. Glass jar of H_2SO_4.

20. Glass jar of HCL.

B. The following equipment was used by NDEC Technical Services Section:

1. Leeds and Northrup pH/Specific Ion/mv meter #7417.

2. 500 ml clear glass jars with lids equipped with Teflon discs (3/well).

3. "Cubie" plastic containers (3/well).

4. Glass jar of HNO_3.

5. Plastic container of H_2SO_4.

6. Plastic container of HCL.

III. Sample Collection Procedures.

Monitoring wells M-8, M-5, M-4, and M-1 were split-sampled between NDEC and HWS/Enviro Service (sub-contractor).

The following personnel were on site:

NDEC - Robert J. Tobin, geologist, Hazardous Waste Section (the author)

- Bill Imig, sampling specialist, Technical Services Section

HWS - Donel Kuhlman, P.E. (Alliance office)

Enviro Service, Inc. - Peter Brixius, lab manager, Scottsbluff
- Verne Gregory

Sampling proceeded in the following pattern:

1. The metal lid of the surface protective casing and the PVC cap were removed. None of the casings were locked.

2. Fill was tagged by unreeling the coiled aluminum tape measure into the well and withdrawing until tension was felt. Static water level was measured in the same manner. This procedure was inaccurate for tagging fill where less sensitivity is required than in the static water level measurement, and therefore the latter recorded data are probably inaccurate as well. This author copied all of the field data from Mr. Kuhlman's field notebook for the 11/7-8/85 and 2/25/86 sampling events as well as the recorded data from the present sampling. There are four instances of decline of fill, among eleven possible instances of comparison. The fill is unlikely to settle, and, unless it was pumped out during the initial submersible-pump-well-purging on 11/7/85, the actual amount of fill should not decline but, if anything, increase.

Depth to fill/bull plug (if no fill), (in feet)

Well #	11/7/85	2/25/86	4/10/86
1	25.0	25.0	25.0
2	30.4	30.5	not available
3	28.9	no value recorded	not available
4	28.1	28.1	28.1
5	25.6	26.8	26.8
6	23.8	29.8	not available
7	28.6	28.8	not available
8	29.7	29.7	29.7

Drillers' logs for the monitoring wells have yet to be received by NDEC, but the consistency of tag depths in the instances of well M-1, M-4, and M-8 are assumed to indicate that these wells have no sand control problem: any fill in these wells must be residue of well development.

On the other hand, submersible-pump-well-purging of M-5 on 2/25/86 (which purged 15 gpm for 3 1/2 minutes, according to Mr. Kuhlman's field notebook) did not decrease the fill volume, or subsequent filling fortuitously accumulated up to the same depth by 4/10/86 (46 days since the 2/25/86 purging) as it had between the first two samplings (110 days), which is unlikely. Assuming that the submersible-pump-well-purging on 2/25/86 (15 gpm for 3 1/2 minutes) was no less effective at removing fill volume in M-5 than the 11/7/85 purging (5 gpm for 3 4/5 months), which is logical, then it is obvious that fill tagging of M-5, at least, was ineffective because the data resulting is inconsistent. This opens up the possibility that it was also ineffective for wells M-2, M-3, M-6, and M-7 for which no fill-tagging data is currently available for the 4/10/86 sampling event, and which probably are not fill-free according to previous data. This conclusion in turn casts doubt upon the static water level measurements, which were measured in the same manner, but which require even greater sensitivity in detecting a difference in tape tension. Note that this latter conclusion with respect to the validity of the water level measurements could have been checked had casing top surveyed elevations been provided to NDEC. With such elevation data in hand as well as the depth to static water level (data in question), water table elevation can be determined (casing top elevation - depth to static water level = water table elevation). This data from the eight wells measured (all ten ought to be measured during each sampling event) could then be contoured to yield instantaneous piezometric maps, internal consistency of trends being a check on the method of static water level measurement employed.

3. The submersible pump was rinsed with deionized water from the squeeze bottle. This was only done prior to the first well purging. Pump, hose, electric cord, and rope were not rinsed between well purgings. Pump rate and duration were recorded. Purged fluid flowed into the bucket and was allowed to spill from the bucket onto the ground. Apparently the purpose of the bucket was to prevent hose discharge from eroding a hole in the shallow soil and loose alluvium. The time of commencement of

purging, and any applicable comments on the color and turbidity of purged water, were recorded.

4. The pump was replaced with the Teflon bailer. Dedicated bailers are not used, the advantage being obviated by the use of one submersible pump. Bailer water samples were drained directly into cups or containers.

5. The S.C./pH meter was calibrated with all three standard fluids (one for S.C. and two for pH) in plastic cups and then two bailing samples in cups were metered and results recorded. The probes were rinsed after calibrating and after each bailing sample.

6. Two 500 ml. brown glass jars were filled; one (phenols) had 2 mls of H_2SO_4 added, the other (pesticides) was not preserved.

7. Four 500 ml. clear glass jars were filled: one (total metals) received 2 mls of HNO_3, one (nitrates) had 2 mls of H_2SO_4 added, and one (chlorides and sulfates) went unpreserved.

8. Two 40 ml "septa" vials were filled; one (TOC) received .2 ml of H_2SO_4, and one (TOX) had 1 drop of HCL added.

9. NDEC S.C./pH measurements and chemical sampling and preserving were completed.

10. The PVC and metal caps were replaced immediately upon completion of sampling of each well.

B. Preservation and Handling

Samples were preserved as noted above and placed in two ice-filled coolers. Note that one set of "duplicate" samples was also taken and preserved in an identical manner to the groundwater samples. This sampling set was of deionized water. The samples were driven by Mr. Kuhlman to Western Laboratories (a subsidiary of HWS) the day after completion of sampling. All samples were labeled with the date, the chemical parameter to be analyzed for, the amount and nature of any preservative employed, and a sample number. This number was indexed to the well number in the field notebook.

C. Chain of Custody

All of the above data were recorded for each sample both on the jar label and on a chain of custody sheet. Receipt of the sample was to be acknowledged by signature of Western Laboratory personnel on the chain of custody form.

D. Laboratory Quality Assurance/Quality Control

Although the laboratories did not perform an identical set of analyses on the groundwater, there were thirteen parameters that were available for comparison. For purposes of calculation the Department's values were used as the reference value. The Lockwood contractor laboratory, performed additional metal analyses on filtered groundwater samples to obtain values which were labeled as dissolved metals. For comparison purposes the NDEC laboratory metal data and the contractor total metal data were used. The NDEC laboratory also performed additional analysis which included pesticides, (none detected) and nitrates.

The data used for the comparisons and calculated percentage differences are shown in Tables 2-5. Also a summary of the percentage differences and calculated average percentage differences is shown in Table 6.

In general, a review of the data shows that, with the exception of total iron, the laboratories had reasonable agreement for the parameters which were compared.

Specifically, the parameters of pH, chloride, specific conductance, manganese and organic carbon exhibited excellent agreement with average percent differences of ten percent or less. Likewise, the parameters of lead, chromium and cadmium had concentrations near detection levels which were reported by both laboratories. The Department's laboratory reported cadmium values greater than the Lockwood contractor laboratory but an elevated blank concentration reported by the Department demonstrated that the true cadmium concentrations were, in fact, near or below detection limits. Quantitative comparisons of low concentrations was considered less important than the finding that both laboratories have shown that these parameters are near detection levels.

Moderate variation ranging from 14 to 30 percent average differences was found for zinc, sulfate, and sodium. The percentage differences for the individual comparisons in this group ranged from -14 percent to 96 percent, which is interpreted to demonstrate less precision in the analytical procedure used for these parameters.

The phenolic values reported had an average percentage difference of 80 percent. The relatively low values reported may account for a substantial portion of the observed differences but the data may also be demonstrating low laboratory precision.

Finally, as noted previously, the total iron concentrations do not agree. The Lockwood contractor iron concentrations range from 100 to 864 percent higher than the Department's iron concentrations. Upon investigation, the Department laboratory reported that the internal quality control checks for iron appeared normal. Further investigation by Lockwood may be necessary to determine the source of variation in the reported iron concentrations.

Table 2
Percent Differences Calculations

WELL NUMBER MW-1

PARAMETER	UNITS	NDEC	LOCKWOOD	% DIFFERENCE
pH		7.0	6.0	-4
Specific Conductance		2706	2600	-4
Chloride		26.3	26	-1
Sulfate		748	920	+23
Sodium		138	148	+7
Organic Carbon		4.8	5	+4
Cadmium		15	5	-66
Chromium		10	10	--
Iron	ug/l	950	9160	+864
Lead		20	25	--
Manganese	ug/l	1690	1650	-2
Zinc		440	380	-14
Phenolics	ug/l	0.05	0.08	+60

Table 3
Percent Differences Calculations

WELL NUMBER MW-4

PARAMETER	UNITS	NDEC	LOCKWOOD	% DIFFERENCE
pH		6.7	6.8	+1
Specific Conductance		4764	4800	-1
Chloride		97.5	92	-6
Sulfate		1069	1630	+52
Sodium		163	320	+96
Organic Carbon		5.99	5	-16
Cadmium		15	5	-16
Chromium		10	30	+200
Iron		920	8300	+802
Lead		50	25	-50
Manganese		4400	4200	-5
Zinc		610	730	+20
Phenolics		0.05	0.06	+20

Table 4
Percent Differences Calculations

WELL NUMBER MW-3

PARAMETER	UNITS	NDEC	LOCKWOOD	% DIFFERENCE
pH		7.5	7.4	-1
Specific Conductance		1082	900	-17
Chloride		31.3	32	+3
Sulfate		153	150	-2
Sodium		166	172	+4
Organic Carbon		3.7	3	-18
Cadmium		15	5	-66
Chromium		10	10	--
Iron		40	80	+100
Lead		20	25	--
Manganese		80	100	+25
Zinc		30	40	+25
Phenolics		0.05	0.13	+160

Table 5
Percent Difference Calculations

WELL NUMBER MW-8

PARAMETER	UNIT	NDEC	LOCKWOOD	% DIFFERENCE
pH		7.4	7.5	+1
Specific Conductance		1256	1100	-12
Chloride		29.3	27	-8
Sulfate		227	320	+41
Sodium		185	207	+12
Organic Carbon		4.56	4	-12
Cadmium		15	5	-66
Chromium		10	10	--
Iron		30	160	433
Lead		20	25	--
Manganese		20	20	0
Zinc		40	50	+25
Phenolics		0.05	.05	--

Table 6
Summary Table of Percent Differences

	MW-1	MW-4	MW-5	MW-8	AVG.
pH	-1	1	-1	1	0
Specific Conductance	-4	-1	-17	-12	-8
Chloride	-1	-6	3	-8	-3
Sulfate	23	52	-2	41	29
Sodium	7	96	4	12	30
Organic Carbon	4	-16	-18	-12	-10
Cadmium	-66	-66	-66	-66	-66
Chromium	--	200	--	--	--
Iron	864	802	100	433	550
Lead	--	-50	--	--	--
Manganese	-2	-5	25	0	5
Zinc	-14	20	25	25	14
Phenolics	60	20	160	--	80

Conclusions and Recommendations

A. Conclusions:

1. Lockwood Corporation has a poor "track record" for meeting groundwater sampling and analysis deadlines and is not currently in compliance with the 2/21/86 NDEC Letter of Warning in that regard. The L.O.W. specified that sampling was to occur during 5/86, analysis from which was to be submitted to NDEC by 7/1/86. This sampling was never conducted.

2. Four of the eight assessment monitoring wells sampled have recently shown concentrations of arsenic, silver, or selenium above the threshold values of 40 CFR 265 Appendix III - EPA Interim Primary Drinking Water Standards. None of these parameters were analyzed by Lockwood in the most recent (4/10/86) sampling event. See Table 1. NDEC split sampling analysis included data for two of these four wells. This indicated acceptable concentrations for those parameters flagged from earlier analyses, yet indicated that one of these wells, as well as one well not previously identified as having had a problem with any of these parameters, had selenium concentrations above the standards.

3. A consistent pattern of improvement is not discernible in the groundwater monitoring results of the assessment monitoring system as a whole. No single well monitored has indicated consistent improvement in all, or a majority, of the parameters analyzed. With the exception of those instances noted in #2 above, all wells have consistently indicated groundwater with Appendix III parameters in concentrations below the Standard threshold values. See Table 1.

4. Well designs are adequate, however there is room for improvement.

5. The Brule Formation, which is likely a part of the uppermost aquifer underlying the site, is not currently being monitored. However, chemical characteristics of the Brule make monitoring unnecessary.

6. The number and location of assessment monitoring wells, with the exception noted in #6 above, are adequate.

7. The requirement of 40 CFR 265.92(e) has not been met. Elevation of the groundwater surface has never been provided for any well during any sampling event. There is no evidence submitted that indicates that ground

level elevations have been surveyed for any of the monitoring wells, thus piezometric data cannot be calculated.

8. The Gering municipal well #6, under its various pseudonyms, may indicate contamination with respect to pH, although this was not yet significant as of 4/18/84. The proximity of this well to Lockwood suggests continued monitoring is necessary.

9. It is apparent on the basis of the QA/QC analysis that the Lockwood contractor and NDEC laboratories had excellent agreement with respect to the parameters of pH, chloride, specific conductance, manganese, and total organic carbon. Lead, chromium, and cadmium concentrations were close to the detection limits of both laboratories. The two labs had a moderate degree of variation with respect to zinc, sulfate, and sodium, indicating less precision in analytical procedure for these parameters. Phenolic concentrations exhibited low precision. Comparison of iron concentration values, and review of NDEC internal quality control checks, indicate that the Lockwood contractor laboratory data for this parameter needs further investigation.

10. With the exception of the concerns noted in #2 above, it is apparent that the natural alkalinity of groundwater and soil in the site area has effectively neutralized the threat to the public health represented by percolation of spent pickle liquor from the surface impoundments.

11. Remedial action pumping and treatment are unnecessary at this site.

12. Well installation procedures, including drilling method choice, and decontamination procedures could be improved.

13. Time-dependent piezometric and isoconcentration mapping has not been presented.

B. Recommendations.

1. Proceed with implementation of the Closure Plan.

2. Survey ground level and casing elevations of the monitoring wells and submit monthly groundwater elevations.

3. Analyze for arsenic, silver, chromium and selenium in all monitoring wells. When all parameters are shown to be consistently below Appendix III standards, then sampling frequency and the list of parameters may be reduced.

4. Until background groundwater concentrations are determined, analysis should continue for the same parameters currently analyzed, plus those recommended above.

5. A sampling and analysis plan should be prepared and submmitted to NDEC.

6. The Gering municipal well #6, etc., should be resampled at least annually by Lockwood or the Nebraska Department of Health and results submitted to NDEC.

7. Monthly piezometric data should be taken for a full year, regardless of any reduction in frequency of chemical sampling that may eventually result from #6 above. Piezometric measurements should be made during all sampling events after this year period and time-dependent piezometric and isoconcentration maps for the three past and all future sampling events should be provided.

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